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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1961 WINTER MEETING IN THE WEST

AT THE

UNIVERSITY OF CALIFORNIA, LOS ANGELES

December 27–29, 1961

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Concerning "Abstracts"

Many people have the not unreasonable idea that the "abstracts" in this Bulletin are abstracts of written texts of which we have the originals. This is not the case. These are the abstracts of speeches which are to be given at the meeting in question. We have no texts, and those who wish more information than an abstract contains must appeal to its author. Every member of the Society has the right to give ten-minute papers before its meetings.

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December 27, 1961 Series II, Vol. 6, No. 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1961 Winter Meeting in the West, University of California at Los Angeles, December 27–29, 1961

THE **1961 Winter Meeting in the West** will be held on the campus of the University of California at Los Angeles. Sessions on Wednesday, Thursday, and Friday, December 27, 28, and 29, are scheduled to be held in the Chemistry Building and in Franz Hall. Since the American Geophysical Union will be meeting on the campus during the same three days, a joint Geophysics session has been planned for Wednesday morning in Schoenberg Hall.

Hotel accommodations within walking distance of the campus are the Claremont Hotel (from $5 single, $8 twin beds) and the Dracker Hotel (from $4 single, $8 twin beds). The following motor hotels, located on Wilshire Boulevard, Los Angeles 24, are close to the Village and the campus: Hotel Westwood Plaza (from $6 single, $8 twin beds), Westwood Colonial House (from $6 single, $8 twin beds), Westwood Inn (from $9 single, $12 twin beds), Cavalier Hotel (singles $10–12), and Del Capri (from $13 twin beds). Other hotels are the Bel Air Hotel on Stone Canyon Road (from $18.50 singles); Bel Air Sands on Sunset Boulevard (from $13 single, $16 double); Miramar Hotel in Santa Monica (from $11 single, $13 twin); Hilton Hotel in Beverly Hills (from $14 single, $19 twin beds); and Surf Rider Inn, Ocean Avenue, Santa Monica (from $9 single, $10 double).

All requests for reservations should be sent directly to the hotel or motel. Since the Christmas and New Year holidays bracket the meeting dates, accommodations should be arranged well in advance.

The **UCLA Residence Halls** are being made available to members of the Society at very reasonable rates. The cost, including maid service and breakfast, is $4 per person for two in a room and $5 for single occupancy. Common restrooms and baths are conveniently located. Provisions have been made for married couples, but the facilities do not allow for housing children under fourteen. Reservations for these accommodations must be made by December 12 by returning the coupon contained in the Bulletin of the Chicago meeting to: Conference Coordinator, Sproul Hall, 582 Gayley Avenue, Los Angeles 24, California.

The **Registration Desk** will be located in the courtyard of the Chemistry Building. Here the usual fee of $1.00 will be collected to help defray expenses of the local committee. The personnel assisting at the registration desk will provide information concerning accommodations, the banquet, personal messages, field trips, ladies' program, and other special arrangements. Requests for nonstandard slide projectors or other equipment should be made well in advance of their anticipated use. Steve Plunkett is in charge of physical arrangements.

Free parking for APS members driving to the University is available in lot No. 2. Other parking facilities on the campus also may be used for a small daily fee.

As in the past, coffee will be served to members in the courtyard of the Chemistry Building near the registration desk and several rooms will be available for conferences.

For **lunches** during the meeting, the Student Union Cafeteria will offer convenient line service. Since the Society has guaranteed a minimum number of patrons, it is urged that this restaurant be used if possible.

Tickets for the **banquet** of the Society will be available at the registration desk. The dinner will be held at 7:30 p.m. Thursday evening at the Miramar Hotel in Santa Monica, a 15-minute drive or bus ride from the University. Preceding the banquet there will be a **cocktail party** starting at

6:30 p.m., also at the Miramar Hotel. Sponsors of this party will be acknowledged on the tickets distributed at the registration desk. The banquet tickets will be $4.50 per person and must be purchased before Thursday noon. We are fortunate to have as our banquet speaker Dr. Leland J. Haworth, of the U. S. Atomic Energy Commission. Professor Frederick Seitz, President of the Society, will preside at the banquet, and Vice-Chancellor W. G. Young of the University of California at Los Angeles will welcome members of the Society to the University campus.

The program, consisting of 131 **contributed papers** and **31 invited papers,** has been arranged with the aid of the local committee under the chairmanship of Professor J. R. Richardson. J. Kaplan, H. E. Bömmel, Byron T. Wright, R. Finkelstein, H. M. McConnell, Ronald Geballe, H. K. Ticho, and Alfredo Baños, Jr., assisted in assembling the invited sessions. Both the Division of Chemical Physics and the Division of Electron Physics are offering symposia during the meeting. Also, as mentioned previously, a joint session with the American Geophysical Union is scheduled for Wednesday morning.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received no later than Wednesday, December 20, at the office of the Local Secretary for the Pacific Coast (see address below). These papers will be presented following sessions that will be designated on a blackboard near the registration desk.

Errata pertaining to abstracts in this issue will be published in a later issue of this Bulletin if received not later than Tuesday, January 2, by Miss Ruth F. Bryans, American Institute of Physics, 335 East 45 Street, New York 17, New York. Do not send in the abstract defaced with erasures and corrections. Write out your corrections in the form "Instead of . . . read . . . ." Add nothing.

H. A. SHUGART
Deputy Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, California

EPITOME OF THE 1961 WINTER MEETING IN THE WEST AT THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES

(Personal names are those of invited speakers.)

Wednesday Morning

10:00 A. Frontiers in geophysics; Malone, Press, Chubb, Ray. Schoenberg Hall.

9:30 B. Solid state I. Chemistry 2224.

9:30 C. Nuclear spectroscopy. Chemistry 2276.

Wednesday Afternoon

2:00 D. Superconductivity and superconducting magnets; Geballe, Deaver, Kunzler, Hake. Chemistry 2250.

1:30 E. Excitation functions. Chemistry 2224.

2:00 F. Resonance physics I. Chemistry 2276.

2:00 G. High-energy nuclear physics I. Franz 104.

Thursday Morning

9:30 H. Accelerators; Richardson, Kelly, Livingston, Mozley, Sands. Chemistry 2250.

10:00 I. Solid state II. Chemistry 2224.

10:00 J. Resonance physics II. Chemistry 2276.

10:00 K. Theoretical physics. Franz 104.

Thursday Afternoon

2:00 L. Theoretical physics; Byers, Nambu, Gell-Mann. Chemistry 2250.

2:00 M. Division of Chemical Physics symposium on magnetic resonance; Gouterman, Townsend, Pershan. Chemistry 2224.

1:30 N. Cosmic-ray, electron, and plasma physics. Chemistry 2276.

Thursday Evening

7:30 Banquet of the American Physical Society; Haworth. Miramar Hotel.

Friday Morning

10:00 O. Symposium of the Division of Electron Physics; Donahue, Carleton, Lippman. Franz 104.

9:30 P. Experimental high-energy physics; Wenzel, Walker, Rosenfeld, Cool, Telegdi. Chemistry 2250.

10:00 Q. Low-energy nuclear physics. Chemistry 2224.

9:30 R. Solid state III. Chemistry 2276.

Friday Afternoon

2:00 S. Plasma physics; Rostoker, Kunkel, Coensgen, Jordan. Chemistry 2250.

2:00 T. High-energy nuclear physics II. Franz 104.

PROGRAMME

WEDNESDAY MORNING AT 10:00

Schoenberg Hall

(J. KAPLAN presiding)

Frontiers in Geophysics

A Joint Invited Session with the American Geophysical Union

A1. Some Implications of Progress in the Atmospheric Sciences. THOMAS F. MALONE, *American Geophysical Union.* (30 min.)

A2. Long Elastic Waves in the Earth. FRANK PRESS, *California Institute of Technology.* (30 min.)

A3. Rocket Astronomy at the Naval Research Laboratory—1961. TALBOT A. CHUBB, *Naval Research Laboratory.* (30 min.)

A4. A Review of the Terrestrial Trapped Radiation Data and Their Interpretation. ERNEST C. RAY, *The State University of Iowa and The Rand Corporation.* (30 min.)

WEDNESDAY MORNING AT 9:30

Chemistry 2224

(I. RUDNICK presiding)

Solid State I

B1. Ultrasonic Determination of the Energy Gap in Superconducting Va and Ta. MOISES LEVY AND ISADORE RUDNICK, *University of California, Los Angeles.*—Using pulsed longitudinal ultrasonic waves the temperature dependent superconducting energy gap was determined for single crystals of Va and Ta. The frequency range used was 158–435 Mc for the Va, and 43–158 Mc for Ta. The ratio of the electrical resistance of the samples at 300°K to that at 4.2°K was 15. The measured zero energy gap was $3.5\pm0.2kT_c$ for Va and $3.2\pm0.2kT_c$ for Ta. The temperature dependence of the gap was in relatively good agreement with theory. In all cases the product of the ultrasonic propagation constant and the normal electron mean free path is less than one. The results are relatively frequency independent. In the superconducting phase there are small oscillations of the ultrasonic attenuation as a function of temperature about the theoretically predicted values for both Va and Ta. The magnitude of these oscillations seems independent of the frequency. There is no evidence of such oscillations when the crystal is kept normal conducting by means of a magnetic field. This latter fact has been verified down to a reduced temperature of 0.68 for Va and to 0.3 for Ta.

B2. Surface Impedance of Thin Superconducting Films. P. V. MASON AND R. W. GOULD, *California Institute of Technology.*—We have investigated the dependence of surface impedance of a thin superconductor on thickness, both theoretically and experimentally. For the theoretical calculation we employed the BCS nonlocal current-potential relationship with coherence length as a parameter, and assumed specular reflection of electrons at the film surfaces. The surface impedance shows a minimum when the thickness is approximately twice the London penetration depth. This minimum vanishes when coherence length is zero. Experimental measurements were made on a strip transmission line[1] formed on a thick superconducting tantalum sheet overlaid with a dielectric and a thin superconducting indium film. Because the surface impedances of the superconductors are inductive, the phase velocity of electromagnetic waves is slower than the velocity of light in the medium. Measurements of the phase velocity, and hence the surface impedances, were made by a transmission resonance technique. The results showed no minimum. This may indicate that the vacuum evaporated indium film was impure, thus reducing the coherence length, or that the assumption of specular reflection was incorrect. The bulk metal penetration depth for indium was found to be 650 ± 75 A; for tantalum, 580 ± 175 A.

[1] D. R. Young, J. C. Swihart, S. Tansal, and N. H. Meyers, Bull. Am. Phys. Soc. 5, 163 (1960).

B3. Superconducting Critical Field of Single Crystal Mo_3Re. R. D. BLAUGHER AND J. K. HULM, *Westinghouse Research Laboratories.*—Critical field measurements were performed on a cylindrical rod of single crystal Mo_3Re. The isothermal, magnetic transitions were extremely sharp and reversible, indicating that the specimen was approaching nearly ideal properties. The principal data are

$$T_c = 9.80°\text{K}, \quad H_0 = 530 \text{ gauss},$$
$$(dH_c/dT)_{T=T_c} = -114 \text{ gauss per deg.}$$

The deviation from parabolic behavior, $D(t)$, indicated a positive maximum value of 0.065. On the basis of this present work, we suggest a possible correlation between the thermodynamic critical field and the "filamentary" critical field noted for the high field superconducting materials.

B4. A 55-Kilogauss Superconducting Solenoid. J. K. HULM, M. J. FRASER, H. RIEMERSMA, A. J. VENTURINO, AND R. E. WEIN, *Westinghouse Research Laboratories.*—In previous work,[1] we have reported the construction of a superconducting solenoid in which a field of 43 000 gauss was attained without the use of ferromagnetic core material. This coil was constructed from 10-mil wire made from a niobium-zirconium base alloy. The superconducting current density was approximately 4×10^4 amp per cm^2. In further work, we have succeeded in doubling the effective superconducting current density in this type of wire. In a new solenoid which has now been tested

a field of 55 000 gauss was attained at the center of the coil. Details of solenoid construction and superconducting performance will be given.

[1] M. J. Fraser *et al.*, Cryogenics (to be published).

B5. Trapped Flux and Critical Currents in Superconducting Thin Film Rings.* J. E. MERCEREAU AND T. K. HUNT, *California Institute of Technology.*—Critical current densities have been determined for superconducting thin film rings by torque measurements of the magnetic moment due to trapped flux. In these rings the maximum magnetic moment is limited by the critical current. This magnetic moment is found to decrease with increasing temperature yielding a temperature dependence of the critical current which is in excellent agreement with the $(T_c-T)^{\frac{1}{2}}$ behavior predicted by the Ginzburg-Landau theory.[1] Current densities approaching 10^6 amp/cm^2 have been observed in tin rings. Supercurrents in the thin film rings are persistent for at least ten hours at temperatures for which the penetration depth is larger than the film thickness. This torque method will be used to investigate the temperature dependence of the magnetic flux quanta which should occur for very thin rings.[2]

* Supported by the National Science Foundation.
[1] V. L. Ginzburg, Soviet Phys.—Doklady **3**, 103 (1958).
[2] J. Bardeen, Phys. Rev. Letters **7**, 162 (1961).

B6. Nuclear Polarization in a Holmium-Indium Alloy.* R. SCHERMER, V. L. SAILOR, C. A. REYNOLDS, F. J. SHORE, H. MARSHAK AND H. POSTMA, *Brookhaven National Laboratory, Upton, N. Y.*—If a polarized beam of neutrons is passed through a polarized nuclear target, the difference in the transmission between the parallel and anti-parallel cases yields information on the spin state of the neutron resonance and on the direction and magnitude of the effective magnetic field, H_{eff}, at the nucleus. We have performed such an experiment using a monochromatic, polarized neutron beam and a nuclear target consisting of a foil of the ferromagnetic alloy, 92% Ho–8% In (atomic%). The apparatus has been described previously.[1] Using an external field of 17.5 koe, the transmission of the sample was measured for the two relative polarization directions at several temperatures between 0.95° and 0.07°K, at the 3.92 ev resonance of Ho^{165} and the 1.456 ev resonance of In^{115}. Both of these resonances are known to have $J=I+\frac{1}{2}$. The sign and magnitude of H_{eff} at the Holmium nucleus are also known. The data were corrected for the effects of spectrometer resolution and the magnetic anisotropy and incomplete magnetic saturation of the sample. H_{eff} at the indium nucleus was determined to be ~130 koe, directed anti-parallel to the external field.

* Work performed under contract with the U. S. Atomic Energy Commission.
[1] V. L. Sailor, H. Marshak, F. J. Shore, C. A. Reynolds, and H. Postma, Bull. Am. Phys. Soc. **6**, 275 (1961).

B7. Pulsed Magnetic Field Studies of the Negative Magnetoresistivities of Dilute Ti-Mn and Cu-Mn Alloys at Low Temperatures.* T. G. BERLINCOURT, R. R. HAKE, AND A. C. THORSEN, *Atomics International.*—Measurements of the low temperature negative magnetoresistivities of dilute Ti–Mn[1] and Cu–Mn[2,3] alloys have been extended to higher magnetic fields by means of pulsed magnetic field techniques. At 4.2°K the observed decreases of resistivity in a transverse magnetic field of 130 kgauss are approximately 5%, 23%, and 26% of the zero field resistivity, respectively, for Ti−0.1 at.% Mn, Ti–1 at.% Mn, and Cu−1 at.% Mn. Saturation of the negative magnetoresistivity is essentially complete in Ti−0.1 at.% Mn below 100 kgauss. A trend toward saturation is strongly evident in Ti−1 at.% Mn and is less marked in Cu−1 at.% Mn. Almost identical behavior is observed for longitudinal and transverse fields in all cases. The data are in accord with earlier evidence[1] for the existence of localized magnetic states in the dilute Ti-Mn alloys.

* Supported by the U. S. Atomic Energy Commission.
[1] R. R. Hake, D. H. Leslie, and T. G. Berlincourt, Bull. Am. Phys. Soc **6**, 146 (1961).
[2] A. N. Gerritsen, Physica **19**, 61 (1953).
[3] R. W. Schmitt and I. S. Jacobs, J. Phys. Chem. Solids **3**, 324 (1957).

B8. Behavior of Ion Pairs in a *p-n* Junction. HOWARD REISS, *Atomics International.*—The polarizability of lithium-acceptor ion pairs in the high field of a *p-n* junction is considered in detail. Many interesting effects are predicted. For example, there are appreciable increases in local dielectric constant. An interesting dispersion curve is computed which makes possible a detailed investigation of the jumping frequency of lithium around an acceptor ion. Interaction with polarized infrared is considered, and anisotropic effects on carrier mobility controlled by ion pair dipole scattering are possible.

B9. The Electrical Conductivity and Seebeck Coefficient of Praseodymium Sulfide between 2° and 1500°K.* G. L. GUTHRIE AND R. CESENA, *General Dynamics/General Atomic.*—The electrical conductivity of praseodymium sulfide has been measured from 2° to 1500°K for several cast samples having chemical compositions varying from $PrS_{1.42}$ to $PrS_{1.48}$. The Seebeck coefficient has been determined for the same samples for temperatures between 500° and 1500°K. Plots of electrical resistivity vs temperature and Seebeck coefficient vs temperature exhibit linearity over large portions of the curves. Certain regularities in the data suggest that the temperature dependent and the temperature independent parts of the electrical resistivity may be due to the same scattering centers. Room temperature conductivities of the samples vary from 250 mho cm^{-1} to 1100 mho cm^{-1}.

* Work supported by the Advanced Research Projects Agency.

B10. Hall Effect and Resistivity of Natural Stannic Oxide Crystals.* E. E. KOHNKE AND E. E. TOLLY, *Oklahoma State University.*—Measurements have been made in the temperature range 250° to 500°K on several *n*-type specimens cut from Bolivian cassiterite. In view of the large (~3.5 ev) forbidden gap, standard analysis was applied to the results, yielding major donor activation energies of about 0.7 ev for samples containing 10^{14}–10^{15} carriers/cm^3 at room temperature. Hall mobilities vary from 10 to 100 cm^2/vsec with effective masses and donor densities estimated around 0.8 m and 10^{20} cm^{-3}, respectively. A second, less-dense donor level near the bottom of the conduction band appears to control the conductivity below room temperature. The origins of these levels are not clear although several possibilities are advanced. The fractional effective masses and relatively high mobilities indicate stannic oxide is a classical broad-band semiconductor unlike the structurally similar material, rutile, which exhibits narrow *3d*-band conduction because of the atomic structure of titanium.

* Supported by the Office of Naval Research.

B11. Galvanomagnetic Coefficients in *p*-Type Gallium Antimonide. H. T. HARPER, H. ROTH,* AND W. B. TEUTSCH, *General Dynamics/General Atomic.*—Conductivity, Hall effect, and magnetoresistance were measured in *p*-type GaSb in the temperature range from 77° to 300°K and in magnetic fields up to 13 kgauss.[1] From the Hall coefficient at room temperature, a carrier concentration of 1.3×10^{17} cm^{-3} is deduced. Such a carrier concentration is commonly found in the purest GaSb and is presumably due to a natural "impurity," perhaps a specific deviation from stoichiometry. Conductivity and Hall effect data on this type of material have been given by several

workers,[2] and our results are consistent with theirs. The three independent second-order magneto-resistance coefficients were determined. The coefficient of transverse magnetoresistance is ~15 times larger than the other two and is approximately equal to the square of the Hall mobility. The latter result and the rather strong magnetic field dependence of the magneto-resistance are indicative of two types of holes; the density and mobility of each have been evaluated using a method similar to that of Champness.[3]

* Now at Research Division, Raytheon Company, Waltham, Massachusetts.
[1] Large Czochralski-grown single crystals were kindly supplied by A. Hatcher and K. Tagami.
[2] See, e.g., D. P. Detweiler, Phys. Rev. 97, 1575 (1955).
[3] C. H. Champness, Phys. Rev. Letters 1, 439 (1958).

B12. Faraday Rotation in Silicon. H. PILLER AND R. F. POTTER, *U. S. Naval Ordnance Laboratory.*—Faraday rotation effects were measured in silicon at wavelengths between 1.05 μ and 3.00 μ with magnetic field strengths up to 20 kgauss using both Polaroid polarizers and stacked AgCl sheets. Verdet coefficients have values between 3.0 and 10^{-2} at 1.05 μ and 0.3×10^{-2} at 3.0 μ in units of deg/gauss cm. The Faraday rotations follow the classical dispersion theory for $\lambda>1.7$ μ, being linear in $(\lambda dn/d\lambda)$ at those wavelengths, and result in a value of 1.4 for m^*/m_e. Faraday rotations departed from linearity at field strengths above 10 kgauss. Measurements were made of the rotation at 298° and 80°K and it was observed that the curve shifted to shorter wavelengths at the lower temperature.

WEDNESDAY MORNING AT 9:30

Chemistry 2276

(S. A. MOSZKOWSKI presiding)

Nuclear Spectroscopy

C1. Bent-Crystal Spectrometer Measurements of $K\alpha$ X-Rays Emitted by Radioactive Sources. E. N. HATCH*, *California Institute of Technology and Zweites Physikalisches Institut der Universität Heidelberg, Germany.*—Wavelengths of several $K\alpha$ x rays emitted from radioactive isotopes in and neighboring the rare earth region have been determined with the two-meter quartz bent-crystal spectrometer at Caltech. The results of the measurements in xu are the following: Sm $K\alpha_2$ 313.043, Sm $K\alpha_1$ 308.390, Eu $K\alpha_2$ 302.477, Eu $K\alpha_1$ 297.824, Gd $K\alpha_2$ 292.432, Gd $K\alpha_1$ 287.746, Tm $K\alpha_2$ 248.592, Tm $K\alpha_1$ 243.859, Yb $K\alpha_2$ 240.934, Yb $K\alpha_1$ 236.184, Lu $K\alpha_2$ 233.610, Lu $K\alpha_1$ 228.834, Hf $K\alpha_2$ 226.605, Hf $K\alpha_1$ 221.805. The estimated maximal error for each measurement is ±0.015 xu. These measurements will be compared with previous measurements using bent crystal spectrometers,[1,2] for which Coulomb excitation targets[1] and electron bombarded targets[2] served as the sources of x rays. The possibility of observing the "isomeric shift" in the Tm $K\alpha$ x rays will be discussed. This possibility has been suggested by Beck and Hauser.[3]

* Present address: Institute for Atomic Research and Department of Physics, Iowa State University, Ames, Iowa.
[1] E. L. Chupp, J. W. M. Du Mond, F. J. Gordon, R. C. Jopson, and H. Mark, Phys. Rev. 112, 1183 (1958).
[2] P. Bergvall, Arkiv Fysik 16, 57 (1959).
[3] F. Beck and U. Hauser (private communication).

C2. Nuclear Resonant Excitation in F^{19} and Mn^{55} Using a Diffraction Monochromator. E. J. SEPPI AND F. BOEHM, *California Institute of Technology, Pasadena, California.*—A monochromator with a bent diffraction crystal having a 2-m radius of curvature has been used to observe nuclear resonant scattering from the 110 kev state of F^{19} and from the 126 kev state in Mn^{55}. The instrument employs a stationary line source (anode of a 250 kev x-ray tube) placed on the focal circle of the bent diffraction crystal. The monochromator is able to furnish monoenergetic electromagnetic radiation in the range 50 to 400 xu (250 to 30 kev) with a width of 0.25 xu for the (310) planes of a 2 mm quartz crystal and of 0.16 xu, corresponding to 170 ev at 110 kev, for the (800) planes of a 1.5 mm germanium crystal. Gamma rays scattered at 135° from targets of LiF and Mn placed in the monoenergetic beam were observed as a function of the wavelength of the incident beam. With the LiF target pronounced resonances 10–15% above background were seen with both crystal planes. A least-squares analysis of the data gives 109.894±0.005 kev for the fluorine resonance position and from the yield a resonance width of $(5.7\pm0.8)\times10^{-7}$ ev was deduced. The measurements on Mn^{55} give 125.95±0.01 kev for the resonance position and $(1.1\pm0.3)\times10^{-6}$ ev for the resonance width.

C3. Lifetimes of the 214-kev Level in Te^{121} and 160-kev Level in Sn^{117}.* M. K. RAMASWAMY, W. L. SKEEL, AND P. S. JASTRAM, *The Ohio State University.*—l-forbidden $M1$ transitions are known to be retarded by factors of 30 to 900[1] compared to single particle estimates. The internal conversion coefficients for the 214-kev transition in Te^{121} and the 160-kev transition in Sn^{117} lead to $M1$ assignments for both. In each case, the ground state is known to have spin $\frac{1}{2}+$. In this region there are available $s_{\frac{1}{2}}$ and $d_{\frac{1}{2}}$ single particle states. The $M1$ assignment is consistent with the assumption that these configurations describe the ground state and first excited state, respectively, with the condition, however, that the transitions should be l forbidden and consequently slower than the single particle rates. By means of delayed-coincidence measurements, we have set an upper limit of 1ns on the lifetimes of the first excited states in Te^{121} and Sn^{117}. These lifetimes correspond to upper limits on the $M1$ retardation factors of 400 for Te^{121} and 150 for Sn^{117}, which are not small enough to rule out the l-forbidden assignment.

* Supported by the U. S. Atomic Energy Commission.
[1] M. K. Ramaswamy, Proceedings of the International Conference on Nuclear Physics, Manchester (1961) (to be published).

C4. On the Half-Life of Gd^{150}. MATTI KARRAS, *University of Arkansas* (introduced by R. B. Moler).—The cross section for the $Eu^{151}(n,2n)Eu^{150}$ reaction using 14.7-Mev neutrons has been determined carefully. Gd^{150} is produced as a decay product of Eu^{150} in amounts large enough to permit an ionization chamber study of the α activity of Gd^{150}. From the accurately known value for the $(n,2n)$ cross section of Eu^{151}, the half-life of Gd^{150} has been determined.

C5. An Integral-Bias Summing Spectrometer for Gamma-Gamma Coincidence and Angular Correlation Studies. JUHANI KANTELE,* *University of Arkansas* (introduced by R. B. Moler).—A new type of scintillation coincidence spectrometer is described which sums pulses from scintillation events occur-

ring simultaneously in two NaI(Tl) crystals, integral-bias discriminator outputs being used in coincidence or in anticoincidence with sum-pulses, to select wanted coincidences. This "sum-peak spectrometer" has a better efficiency and resolution than an ordinary coincidence spectrometer, from which it can be obtained by an easy modification. In a 4-π geometry the system can be used sometimes to measure the total disintegration energy of electron-capturing nuclei, by summing the internal bremsstrahlung, x-ray, and gamma pulses. As no pulse-height selector windows are involved, the performance of the spectrometer is insensitive to minor electronic drifts, which also makes this system especially useful in angular correlation studies. Here it occasionally allows a simultaneous measurement of several angular correlation functions. It also offers the possibility of using a known gamma cascade as an internal monitor, which reduces uncertainties due to geometrical and other effects.

* On leave from University of Helsinki, Finland.

C6. Determination of the Beta-Spectrum of Tritium Using a Liquid Scintillation Spectrometer and a Multi-Channel Analyzer. W. LOHMANN, E. H. CATHEY, JR., AND W. H. PERKINS, *Departments of Radiology and Medicine, University of Arkansas Medical Center, and Radioisotope Service, VA Hospital, Little Rock, Arkansas.*—A direct determination of the beta-spectrum of tritium has been made using a combination of a liquid scintillation spectrometer and a 400-channel analyzer. The instrumental setup as well as the converting and matching unit, used for connecting the instruments, are described. As counting solution a PPO, POPOP toluene dioxane solution was used in which the tritiated water was distributed uniformly. The Fermi plot shows that the experimental data are fitted well by a straight line from the maximum energy at 18 kev down to 2.9 kev.

C7. Longitudinal Polarization of Bi^{210} β Rays.* A. L. VAMPOLA† AND A. H. WEBER, *Saint Louis University.*—The longitudinal polarization of Bi^{210} β particles was determined as a function of v/c using the double Mott-scattering method. Corrections for depolarization effects were made using theoretical calculations and by comparing with results obtained for P^{32} with the same apparatus. Scattering asymmetry was determined for five velocity groups within (0.449–0.798) v/c. The electron polarization was measured as $(0.53–0.73)\pm0.06$ and $(0.59–0.77)\pm0.06$, in units of $-v/c$, for v/c centered at 0.71 and 0.80, respectively, including crude corrections for scatterer and source depolarizations. The electron polarization for the three lower velocities could not be calculated due to nonapplicability of the formulas. The results are consistent with time-reversal invariance within a phase angle of $+3-0$ deg.

* Supported in part by the Research Corporation.
† Now at Convair—San Diego, California.

C8. L/K-Capture Ratio of Zn-65. D. C. CONWAY AND A. G. SANTOS-OCAMPO, *Purdue University.*—The L/K-capture ratio of Zn-65 was found to be 0.119 ± 0.007 in the high-pressure proportional counter previously described[1] with either zinc dimethyl or zinc diethyl as the volatile source. The activity decreased continuously throughout each run, but repetitive determinations of the ratio with the same counter filling were identical. Various possible explanations for the fact that the experimental ratio is larger than the theoretical ratio of 0.097[2] are examined.

[1] A. G. Santos-Ocampo and D. C. Conway, Phys. Rev. 120, 2196 (1960).
[2] H. Brysk and M. E. Rose, Revs. Modern Phys. 30, 1169 (1958).

C9. Theoretically Determined Nuclear Particle Spectra.* ALDEN MCLELLAN AND DAVID B. BEARD, *University of California, Davis.*—Neutron spectra from many medium and heavy nuclei excited to more than 20 Mev have been calculated by a rigorous application of the statistical theory of individual particle excitations. Multiple particle emission has been consistently included. The only parameters used were nuclear size and well-depth determinations from various scattering experiments; no parameters were used from any particle spectra measurements. While each single particle emission spectrum gave a pronouncedly curved graph when plotted on a semilog plot as a function of energy, the appropriately weighted sum of multiple particle emissions gave essentially a straight line. Particularly when the diffuseness of the nuclear well[1] and the centrifugal potential barrier are taken into account, an excellent fit to experimental observations was obtained. We wish to emphasize that the fit was not due to a single parameter obtained from particle spectra experiments. The calculations were prepared on the Davis Campus IBM 1620 computer and performed by the Western Data Processing Center at Los Angeles.

* Research Supported in part by the U. S. Atomic Energy Commission.
[1] D. B. Beard, Phys. Rev. Letters 3, 432 (1959).

C10. A Calculation of the Two-Neutron Binding Energy and the Level Spectrum of O^{18} from the Brueckner-Gammel-Thaler Potential.* J. F. DAWSON, I. TALMI,† AND J. D. WALECKA, *Stanford University.*—The two-neutron binding energy and excitation spectrum of O^{18} are computed using the Brueckner-Gammel-Thaler potential (which contains a hard core). The problem is discussed within the framework of the Bethe-Goldstone theory[1] using harmonic oscillator wave functions as the unperturbed solutions. The interaction is diagonalized among the degenerate states, and matrix elements are computed by a transformation to relative and center-of-mass coordinates.[2] Various approximations were used for hard-core energies in the relative s-states. The most reliable one was obtained by a numerical integration of the relative s-wave Schrödinger equation. The ordering of the first five states of O^{18} is given correctly, and the binding energy and level spacings are surprisingly close to the experimental values.

* Research supported by the U. S. Air Force Office of Scientific Research.
† On leave from the Weizmann Institute of Science, Rehovoth, Israel.
[1] H. Bethe and J. Goldstone, Proc. Roy. Soc. (London) A238, 551 (1957).
[2] V. V. Balashov and V. A. Eltekov, Nuclear Phys. 16, 423 (1960).

C11. Quantum Mechanical Wave Function as the Potential of the Vibrational Motion of a Compressible Nucleus. RICHARD L. MOORE, *R. L. Moore Consultants.*—Utilization of completely classical methods of hydrodynamics, following J. P. Wesley's suggestions[1] $\nabla\Psi$ (where Ψ is the Schrödinger wave function), is shown to be interpretable as the product of the fluid density and the velocity vector of the vibrational field of a compressible nucleus, provided the potential function U of the wave equation (in cylindrical coordinates) is assumed to be proportional to the square of the radial coordinate.[2] The density field is gaussian with standard deviation $1/2\pi$ times the Compton wavelength. The Planck constant is thus shown to arise from a fundamental length, the standard deviation of the mass distribution function. The scalar of the velocity field is proportional to $rM[\alpha; 2; (r/\lambda)^2/2]$. M is the confluent hypergeometric function. α is zero or a negative integer to obtain an analytic solution. λ is a vibration length related to α. The boundary conditions determine whether higher order modes of vibrations correspond to internal vibrations, in which the nuclear surface does not move (i.e., a velocity node at the surface), or to pulsations in which the nuclear surface moves radially (an antinode at the surface). The moment of inertia of a "Gaussian" nucleus is substantially less than that of a nucleus with uniform density of the same mass and radius and accordingly is in agreement with experiment.

[1] J. P. Wesley, Phys. Rev. 122, 1932 (1961), and unpublished mss.
[2] R. L. Moore, J. Electron. Contr. (to be published, 1961).

C12. Symmetrical Series of Numbers as Key to Calculation of Numbers of Stable Isotopes. N. EFREMOV, *New York,*

New York.—Symmetrical series of numbers can be very useful to explain the relationship between many physical magnitudes such as the number of isotopes of the chemical elements. These series consist of several number members (3, 5, 6, 7, etc.) and may be either simple or complex. We can present the following as examples of both types of symmetrical series of numbers:

Simple symmetrical series of seven members:	222 1 222
Simple symmetrical series of three members:	3 1 3
Complex symmetrical series of six members:	241 415

As we can see from the above, a simple symmetrical series has a center of symmetry represented by a central small number (1) while on either side of it stand identical numbers. In the complex symmetrical series the sum of the first member (2) and the fourth (4) is equal (2+4=6) to the sum of the third member (1) and the sixth (5) member (1+5=6). Both pairs of number on the last series are symmetrically located in relation to an imaginary center of symmetry. By way of application of the above *a priori* considerations, we point out that the seven-member series represents the series of numbers of stable isotopes of H-2, He-2, Li-2, Be-1, B-2, C-2, N-2. The three-member series represents the same for the isotopes of O-3, F-1, Ne-3.

WEDNESDAY AFTERNOON AT 2:00

Chemistry 2250

(H. E. BÖMMEL presiding)

Superconductivity and Superconducting Magnets

Invited Papers

D1. Isotope Effect in Superconductors. T. H. GEBALLE, *Bell Telephone Laboratories.* (30 min.)

D2. Quantization of Magnetic Flux in Superconductors. B. S. DEAVER, *Stanford University.* (30 min.)

D3. Superconductivity and High Field Magnets. J. E. KUNZLER, *Bell Telephone Laboratories.* (30 min.)

D4. Superconductivity in Transition Metal Alloys. R. R. HAKE, *Atomics International.* (30 min.)

WEDNESDAY AFTERNOON AT 1:30

Chemistry 2224

(C. A. BARNES presiding)

Excitation Functions

E1. Excitation Function for Gamma Radiation from $C^{12}+\alpha$.* J. D. LARSON AND R. H. SPEAR, *California Institute of Technology, Pasadena* (introduced by T. Lauritsen).—A preliminary study of the excitation function for gamma radiation from $C^{12}(\alpha,\gamma)O^{16}$ has been made for energies E_α from 3.0 to 9.3 Mev using the ONR tandem accelerator, a 4×4 in. NaI (Tl) crystal at 45° to the beam axis, and a natural carbon target of thickness approximately 60 μg/cm^2. Resonances for capture gamma radiation were observed at E_α=3.59, 4.26, 5.80, 7.08, 7.89 and 8.11 Mev, corresponding to levels in O^{16} at 9.85, 10.36, 11.51, 12.47, 13.08, and 13.24 Mev. In each case the radiation observed was to the ground state, except at E_α=4.26 Mev, where a gamma ray of energy (6.8±0.3) Mev was observed and attributed to radiation from the 6.92-Mev 2^+ state of O^{16} produced by cascade decay of the 10.36-Mev 4^+ state. It is possible that the "ground state" radiation observed at E_α=8.11 Mev may be largely or completely due to summing of cascade gamma rays. The 3.59- and 5.80-Mev resonances have been previously observed.[1] The excitation function for 4.43-Mev radiation from $C^{12}(\alpha,\alpha'\gamma)C^{12}$ showed resonances at E_α=7.93, 8.15, 8.97, and 10.18 Mev, in good agreement with previous work.[2]

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] Meads and McIldowie, Proc. Phys. Soc. (London) **A75**, 257 (1960).

[2] G. F. Mitchell, E. B. Carter, and R. H. Davis, Bull. Am. Phys. Soc. 6, 227 (1961).

E2. Excitation Function for Gamma Radiation from $O^{16}+\alpha$.* J. D. PEARSON AND R. H. SPEAR, *California Institute of Technology, Pasadena.*—A preliminary study has been made of the excitation function for gamma radiation from $O^{16}(\alpha,\gamma)Ne^{20}$ for energies E_α from 4.8 to 10.0 Mev using a 4×4 in. NaI (Tl) crystal, and an oxide target prepared by radio frequency heating of tungsten in an atmosphere of oxygen depleted in O^{18}. Resonances for capture radiation were observed at E_α=4.95, 5.40, 5.96, 6.56, 6.95, 7.97, 8.20, and 9.43 Mev, corresponding to levels in Ne^{20} at 8.69, 9.05, 9.50, 9.98, 10.29, 11.11, 11.29, and 12.27 Mev, respectively. Results of coincidence studies of cascade radiation will be presented, and evidence will be given suggesting that the previously unreported 10.29-Mev state is the first $T=1$ state of Ne^{20}. The excitation function for 6.1-Mev radiation from $O^{16}(\alpha,\alpha'\gamma)O^{16}$ was found to be resonant at E_α=9.60 Mev, corresponding to a level at 12.41 Mev in Ne^{20}.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E3. Inelastic and Elastic Scattering of Protons by Li^6.* W. D. HARRISON AND A. B. WHITEHEAD, *California Institute of Technology, Pasadena.*—The scattering of protons by Li^6 has been observed up to 10 Mev at lab angles of 86.4°, 120°, and 152.5°. Energy steps of approximately 100 kev were used. The target thickness was of the order of 30 kev while the resolution of the surface barrier particle spectrometer[1] was 50 kev. No

strong resonances were in evidence in the ground state and first excited state proton groups between E_p of 5 Mev and E_p of 10 Mev. Protons from the second excited state were barely resolvable in the particle spectra, while a continuum of lower energy particles made identification of the higher levels in Li^6 impossible.[2] Alpha and He^3 particles from the reaction $Li^6(p,He^3)\alpha$ were readily identified in the spectra. Detailed yield curves of the proton groups corresponding to the ground and first excited states will be presented.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Dearnaley and Whitehead, Harwell Rept. AERE R 3662.
[2] K. W. Allen, E. Almquist, and C. B. Bigham, Phys. Rev. **99**, 631A (1955).

E4. Reaction $D(p,\gamma)He^3$ at 30 kev. G. GRIFFITHS, M. LAL, AND C. SCARFE, *University of British Columbia* (introduced by M. Bloom).—We have measured the cross section for the reaction $D(p,\gamma)He^3$ in the energy range from 48 to 24 kev, using thick heavy ice targets. Based on measurements at 0° and 90°, the angular distribution has the form $\sin^2\theta+(0.25\pm0.08)$, being more isotropic than at higher energies. The total cross section is given by $\sigma(E)=(6.8\pm1.3)10^{-28}E^{-1}\exp(-31.38E^{-\frac{1}{2}})$ cm² for laboratory energy E in kev. This simple energy dependence does not fit the available data from 24 kev to 1.8 Mev. In addition, there is clear evidence that the energy dependence of the $\sin^2\theta$ part is different from the energy dependence of the non-$\sin^2\theta$ part. The energy dependence of the main $\sin^2\theta$ part of the yield has been fitted on the basis of a direct radiative capture theory assuming incident P waves. The factors affecting the energy dependence suggested by this theory have been evaluated for S and P waves and these give good fits to the separate energy dependences of the non-$\sin^2\theta$ and $\sin^2\theta$ parts of the yield. The $D(p,\gamma)He^3$ S-wave cross section modified for incoming neutrons and extrapolated to thermal energies agrees within a factor of 2 with the measured thermal n-d capture cross section.

E5. Nuclear Reaction Cross Sections for 10.3 Mev Protons on Carbon and Cu.* G. IGO AND B. WILKINS, *Lawrence Radiation Laboratory, University of California, Berkeley.*—The reaction cross section σ_R is measured by direct attenuation of the incident beam intensity I_0 to an intensity I by an absorber of C or Cu of thickness N atoms per square centimeter. Since $N\sigma_R$ is always less than 10^{-3}, the quantities I_0 and I_0-I are most readily accessible to measurement. The relation $(I_0-I)/NI_0=\sigma_R-\sigma_{CE}$ relates the measured quantities to σ_R providing the compound elastic scattering cross section σ_{CE} is small or if it may be estimated accurately. In addition, a correction for the shape elastic scattering cross section σ_{SE} must first be made using elastic scattering data. For C and Cu, $\sigma_R-\sigma_{CE}$ is 285 ± 17 mb and 979 ± 20 mb, respectively. The sum of the measured quantities, σ_R and $\sigma_{SE}+\sigma_{CE}$ for C is considerably smaller than the predicted value, 710 mb, for σ_R from the optical model at 10 Mev.[1] The quantity $\sigma_R-\sigma_{CE}$ for Cu is considerably larger than the predicted value, 840 mb, at 10 Mev from the optical model.[1]

* Supported by the U. S. Atomic Energy Commission.
[1] R. D. Albert and L. F. Hansen, Phys. Rev. **123**, 1749 (1961). Surface absorption optical model calculations by F. Bjorklund and S. Fernbach are quoted.

E6. Excitation Function of $O^{16}(p,p'\gamma)$ to 10.6 Mev.* R. F. STURGEON, JR.,† J. A. BECKER, AND J. D. FOX, *Florida State University.*—The excitation functions for production of the 6.12 and 6.92 Mev γ rays in O^{16} by protons have been measured from thresholds to 10.6 Mev. The γ rays were detected at 90° from the beam axis with a 3-crystal scintillation pair spectrometer. A gas target of CO_2 at 6.7 cm Hg pressure was bombarded with proton beams of 2 μa. The yield of the oxygen gamma rays was determined relative to that of the carbon 4.43 Mev γ ray for each run of 200 μcoul. The excitation functions were obtained by normalization to the data of Adams *et al.*[1] on the $C^{12}(p,p'\gamma_{4.43})$ reaction. Resonances were observed at incident proton energies of 6.88, 7.23, 7.43, 7.88 ,8.31, 8.86, 9.19, and 9.98 Mev.

* Supported in part by the U. S. Air Force Office of Scientific Research
† Now at Chance-Vought Astronautics, Dallas, Texas.
[1] H. S. Adams, J. A. Becker, J. D. Fox, N. P. Heydenburg, and G. M. Temmer, Bull. Am. Phys. Soc. 5, 404 (1960).

E7. $Na^{23}(p,\alpha)Ne^{20}$ Reaction in the Energy Range 200 to 450 kev.* THORNTON R. FISHER, *California Institute of Technology, Pasadena.*—The total cross section for the reaction $Na^{23}(p,\alpha)Ne^{20}$ has been measured in the proton energy range from 200 to 450 kev. Four resonances have been observed at proton bombarding energies of 286, 338.5, 374, and 444 kev. The 286 and 338.5 kev resonances had been found in previous studies of this reaction; the 374 and 444 kev resonances had been previously observed in $Na^{23}(p,\gamma)Mg^{24}$, but not in $Na^{23}(p,\alpha)Ne^{20}$. Upper limits have been placed on the alpha yield from known resonances in $Na^{23}(p,\gamma)Mg^{24}$ at 250.8 and 307.8 kev, and on the nonresonant cross section in the energy range observed. The results indicate that the main contribution to the $Na^{23}(p,\alpha)Ne^{20}$ reaction rate in stars of temperature $5\text{–}8\times10^8$ °K does not come from the energy region 200–450 kev but from a known resonance at 594 kev. Angular distribution measurements at 286, 338.5, and 374 kev, lead to spin and parity assignments of 2^+, 3^-, and 4^+ for these states. The measured widths for the states at 286 and 338.5 kev are 1.7 and 0.7 kev. The data at 374 and 444 kev are consistent with the widths previously measured for these states in $Na^{23}(p,\gamma)Mg^{24}$.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E8. $O^{16}(p,\gamma)F^{17}$ Excitation Function in the Region of the 3.10-Mev State of F^{17}.* JOHN DOMINGO, *California Institute of Technology, Pasadena.*—A previous investigation[1] of the $O^{16}(p,\gamma)F^{17}$ reaction revealed no pronounced anomaly in the capture cross section at a bombarding energy of $E_p=2.66$ Mev where an anomaly had been observed in the $O^{16}(p,p)$ reaction. Recent calculations by Christy and Duck[2] have indicated that an anomaly should be present, and a detailed study of the reaction was therefore undertaken in this energy region. The yield of the capture gamma radiation was measured at 90° using a NaI(Tl) detector for bombarding energies in the range $E_p=2.58$ to 2.78 Mev. The capture radiation leading to the 0.500-Mev state of F^{17} showed an interference anomaly at a bombarding energy corresponding to the 3.10-Mev state of F^{17}. No anomaly was observed in the yield of the capture radiation leading to the ground state of F^{17}. The experimental results will be compared with a theoretical calculation.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] R. A. Laubenstein, M. J. W. Laubenstein, L. J. Koester, and R. C. Mobley, Phys. Rev. **84**, 12 (1951).
[2] R. F. Christy and I. Duck, Nuclear Phys. **24**, 89 (1961).

E9. Activation Analysis of Yttrium and Ytterbium.* O. M. HUDSON, JR., AND I. L. MORGAN, *Texas Nuclear Corporation.*—The thermal neutron capture cross section in Yb^{168} has been measured relative to this cross section in Au^{198}. Enriched samples of Yb were used. In Y^{89}, measurements of $\sigma(p,pn)$ at $E_p=730$ Mev and of $\sigma(n,2n)$ and $\sigma(n,\alpha)$ at $E_n=16$ Mev have been made. The activity produced in the samples was measured with a 2×2 in. well counter and a 256 channel analyzer.

* Supported by U. S. Air Force Aerospace Medical Center, Brooks Air Force Base, Texas.

E10. Elastic Scattering of Deuterons by Li^7.* JAMES L. C. FORD, *California Institute of Technology, Pasadena.*—The elastic scattering of deuterons by Li^7 nuclei has been studied as a function of both angle and energy from 0.400 to 1.800 Mev.

The scattering cross sections tend to be lower than the Rutherford value below about 0.850 Mev and then rise to values several times the Rutherford value for higher energies. A prominent anomaly occurs in the scattering cross section near 1 Mev where the reaction cross sections also show resonance, while there is no obvious anomaly corresponding to the reaction resonance near 0.800 Mev. Excitations curves and angular distributions will be presented, as well as results from a preliminary analysis.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E11. Analysis of the Two-Nucleon Stripping Reaction $C^{12}(He^3,p)N^{14}$.* J. CERNY, N. K. GLENDENNING, B. G. HARVEY, R. H. PEHL, AND E. RIVET, *Lawrence Radiation Laboratory and Department of Chemistry, University of California, Berkeley.*—The angular distribution of protons from the $C^{12}(He^3,p)N^{14}$ reaction induced by 31.2 Mev He^3 ions has been obtained. Differential cross sections for the transitions to the ground state and to the 2.31-Mev and 3.95-Mev excited states were measured from 9.5 to 154.5 deg in the laboratory system using a 150-mil thick lithium-drifted radiation detector[1] with a sensitive thickness of 135 mils. These results and those of Priest *et al.*[2] at 13.9 Mev will be compared with a two-nucleon stripping theory.[3] The nuclear structure factors of the original theory—formulated for (α,d) reactions—have been modified to permit the captured proton and neutron to be in a singlet as well as a triplet state.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] J. H. Elliott, Nuclear Instr. and Methods **12**, 60 (1961).
[2] J. R. Priest, D. J. Tendam, and E. Bleuler, Phys. Rev. **119**, 1295 (1960).
[3] N. K. Glendenning, Nuclear Phys. (to be published).

E12. Transfer Reactions Resulting from 28-Mev N^{14} Particles on Cl^{35}. K. S. TOTH AND E. NEWMAN, *Oak Ridge National Laboratory.**—Thick targets of RbCl were bombarded with 28-Mev N^{14} ions accelerated in the Oak Ridge 63-in. cyclotron. Yields per incident particle were obtained, as a function of bombarding energy, for two transfer reactions: $Cl^{35}(N^{14},O^{15})S^{34}$ and $Cl^{35}(N^{14},N^{15})Cl^{34m}$. The detector consisted of a NaI crystal connected to a 256-channel pulse-height analyzer. In the case of the proton transfer reaction the positrons emitted by O^{15} (2.1 min) were detected by means of their annihilation radiation. For the neutron transfer case the 145-kev γ ray emitted by Cl^{34m} (32 min) was identified. Cross sections were determined as a function of bombarding energy by differentiating the experimental yield curve. The cross sections will be compared with the "universal" curve obtained for neutron transfers.[1]

* Operated for the U. S. Atomic Energy Commission by Union Carbide Corporation.
[1] M. L. Halbert, T. H. Handley, J. J. Pinajian, W. H. Webb, and A. Zucker, Phys. Rev. **106**, 251 (1957).

E13. Proton Scattering From Pb^{208} at 31 Mev.* G. G. GIGAS, D. W. DEVINS, AND H. H. FORSTER, *University of Southern California, Los Angeles.*—Differential scattering cross sections for 31 Mev protons scattered elastically from enriched Pb^{208} foils of 15 mg/cm^2 were determined for angles varying between 6° and 156° in the center-of-mass system. An optical model analysis of the data following the method of Nodvik, Duke, and Melkanoff[1] and using a surface-plus-volume-potential gave a best fit with the following parameters: $R_0=1.20f$, $a=0.656f$, $b=2.000f$, $V=51.8$ Mev, $W_1=9.7$ Mev, while W could be varied between 0 and 4 Mev without any apparent effect on the fit. The angular distribution of protons scattered inelastically from the 3^- level at 2.62 Mev shows a diffractionlike structure; the differential scattering cross section decreases at small angles in accordance with the predictions of Kromminga and McCarthy[2] for an odd parity transition. The experimental data will be compared with results obtained using the adiabatic approximation of Blair.[3]

* Work supported in part by the U. S. Atomic Energy Commission.
[1] Nodvik, Duke and Melkanoff, Phys. Rev. (to be published).
[2] A. J. Kromminga and I. E. McCarthy, Phys. Rev. Letters **6**, 62 (1961).
[3] J. S. Blair, Phys. Rev. **115**, 929 (1959).

E14. Elastic Scattering of Protons from He^3.* T. A. TOMBRELLO,† C. M. JONES, G. C. PHILLIPS, AND J. L. WEIL, *Rice University.*—The elastic scattering of protons from He^3 has been observed in the energy range from 2.0 to 4.8 Mev using a precision small-volume gas scattering chamber. Excitation functions have been measured at the center of mass angles 70.12°, 90°, 125.26°, 140.77°, and 155°, and angular distributions have been measured for proton energies of 2.01, 3.01, 3.99, and 4.54 Mev. A preliminary phase shift analysis of these data will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.
† Present address: California Institute of Technology.

WEDNESDAY AFTERNOON AT 2:00

Chemistry 2276

(H. A. REICH presiding)

Resonance Physics I

F1. Adiabatic Demagnetization in the Rotating Frame: Observation of the Demagnetized State. A. G. ANDERSON, *IBM Research Laboratory,* AND S. R. HARTMANN,* *University of California, Berkeley.*—Following the work of Redfield[1] and recent results of Slichter and Holton,[2] it is of interest to examine complete adiabatic demagnetization in the rotating frame (ADRF) and observation of this demagnetized state in homogeneously broadened systems by normal NMR techniques. Such observations have been made of Li^7 in lithium metal; the ADRF state is readily observed, having a signal comparable with the normal NMR signal and having a line shape[3] in either absorption or dispersion mode which had the appearance of a derivative of the normal signal. Pulses applied to Na^{23} in NaCl after ADRF also produce large-output free-induction signals which appear like derivatives of the normal case. After ADRF, Zeeman energy is zero and dipole-dipole energy is large. The observed relaxation time in the ADRF state is of order T_1 at high dc field where Zeeman and dipole-dipole energies are weakly coupled and becomes short at low dc fields. Satellite lines and coupling between systems have been observed in the ADRF state.

* Supported in part by the National Science Foundation and the Office of Naval Research.
[1] A. G. Redfield, Phys. Rev. **98**, 1787 (1955).
[2] C. P. Slichter and W. C. Holton, Phys. Rev. **122**, 1701 (1961).
[3] S. R. Hartmann and A. G. Anderson, Bull. Am. Phys. Soc. **6**, 307 (1961), abstract F2.

F2. Adiabatic Demagnetization in the Rotating Frame: Simple Theory. S. R. HARTMANN,* *University of California, Berkeley* AND A. G. ANDERSON, *IBM Research Laboratory.*—A

simple heuristic theory is presented to explain the results of a number of transient nuclear magnetic resonance experiments[1] performed after adiabatic demagnetization in the rotating frame, ADRF. The magnitude and shape of the absorption at $\omega \approx 0$, Ω, and 2Ω, where Ω is the nuclear resonance frequency of the spin system, is obtained together with the resulting free-induction decay signal after a short intense rf pulse. It is found that after ADRF the line shape at $\omega \approx \Omega$ is $[\Omega/\langle\Delta\omega_L^2\rangle^{\frac{1}{2}}] \cdot [(\omega-\Omega)/\omega]$ times the shape observed under the usual conditions while the observed free induction decay signal after a $\theta°$ rf pulse is given by

$$\langle M\rangle = M_0(1/\langle\Delta\omega_L^2\rangle)^{\frac{1}{2}}\langle d\langle\mathfrak{M}\rangle/dt\rangle \times\{[\langle\Delta\omega_{aa}^2\rangle\cos\theta+\langle\Delta\omega_{ab}^2\rangle]/[\langle\Delta\omega_{aa}^2\rangle+\langle\Delta\omega_{ab}^2\rangle]\},$$

where $\langle\mathfrak{M}\rangle$ is the free-induction decay signal observed under the usual conditions, and $\langle\Delta\omega_{aa}^2\rangle$ and $\langle\Delta\omega_{ab}^2\rangle$ are the second moments of a spins due, respectively, to other a spins and to b spins. The quantity $\langle\Delta\omega_L^2\rangle$ is a measure of the magnitude of the dipole-dipole interaction. Similar results were obtained using a quantitative theory.

* Supported in part by the National Science Foundation and the Office of Naval Research.

[1] A. G. Anderson and S. R. Hartmann, Bull. Am. Phys. Soc. 6, 507 (1961), abstract F1.

F3. Paramagnetic Resonance of Ultrasound in Ruby and Fluorite. W. I. Dobrov and M. E. Browne, *Lockheed Research Laboratory.*—Magnetic field dependent attenuation of microwave ultrasound in ruby and in CaF_2 (0.2% Eu^{2+}) has been observed at 1.6°K. *X*-band phonons were generated using techniques developed by Jacobsen[1] and others. Transmission of longitudinal waves was achieved by pressing the sample between two quartz transducer rods. By integrating pulses and plotting only the intensity change of a given transmitted pulse as a function of magnetic field, it was possible to observe directly paramagnetic ultrasonic resonance. By measuring the change in ultrasonic absorption at magnetic resonance as a function of the angle between the magnetic field and the direction of sound propagation, the angular dependence of spin-phonon transition probabilities was directly obtained. Line shapes in ruby were recorded with sufficient accuracy to make possible determination of the ratio of line moments, $r=\langle\Delta\nu^4\rangle^{\frac{1}{2}}/\langle\Delta\nu^3\rangle^{\frac{1}{3}}$. This ratio, which characterizes a particular line shape, was found to be close to the Gaussian value of 1.32. Measurements on two ruby samples with an effective spin concentration ratio of 6:1 (the more dilute containing 0.05% Cr) yielded the same value of the magnetoelastic constant,[2] $G=1.7\times10^{-15}$ ergs, for waves propagated along the c axis. For ⟨111⟩ propagated waves in CaF_2, G is of the order of 10^{-16} ergs. Direct spin-lattice relaxation times were obtained.

[1] E. H. Jacobsen, Phys. Rev. Letters 2, 249 (1959).
[2] E. B. Tucker, Phys. Rev. Letters 6, 183 (1961).

F4. Effect of Quadrupolar Polarizability upon Field Gradient in Tetragonal Lattices.* T. T. Taylor, *University of California, Riverside.*—Pursuant to an investigation of possible sources of the electric field gradient in metallic indium described earlier by R. R. Hewitt and the author,[1] the effect of externally induced quadrupole moments in the ion cores has been analyzed. Calculations of the electric field gradient at the origin in a tetragonal lattice of quadrupoles have been carried out at eight figures for several values of c/a between 0.50 and 3.20 and for the following cases: (a) ions at 0 0 0, (b) ions at ½ ½ ½, (c) ions at both 0 0 0 and ½ ½ ½. The c/a value of approximately 1.52 for the body-centered tetragonal lattice of indium falls near one of the zero points of the calculated curve and, assuming a reasonable value for the quadrupolar polarizability of the In^{3+} ion, the effect in this material will be small. In other substances, however, the effect could easily be appreciable.

* Supported in part by the National Science Foundation.

[1] T. T. Taylor and R. R. Hewitt, Bull. Am. Phys. Soc. 6, 105 (1961).

F5. Proton Relaxation Enhancement. J. Eisinger, W. E. Blumberg, and R. G. Shulman, *Bell Telephone Laboratories, Inc.*—It is well known that the spin lattice relaxation rate of protons in water is increased by the presence of paramagnetic ions in the solution. This effect can be described by an approximate form of the Solomon-Bloembergen theory[1] $1/NT_1=\alpha p\tau_c$, where α is constant which depends on the dipole field of the ion, N is the ion concentration, p is the number of protons in the hydration sphere, and τ_c is the ion proton correlation time. We have found that $1/NT_1$ can be greatly enhanced when the ions are bound to molecules also present in the solution. This is explained by a longer value for τ_c accompanied by only a small decrease in p. If the ion is bound in a molecular site which is almost inaccessible to water molecules, the decrease in p is the predominant effect and T_1 is lengthened. We have studied the binding of transition metal ions to DNA by methods based on the above argument and conclude that Mn^{2+}, Cu^{2+}, and Cr^{3+} are bound to the exterior phosphate groups of DNA but that Fe^{3+} seems to seek an interior site. The maximum number of ions taken up corresponds to about 0.6 of the number of phosphate groups.

[1] I. Solomon, Phys. Rev. 99, 559 (1955); N. Bloembergen, J. Chem. Phys. 27, 572, 595 (1957).

F6. Two Quantum Transitions in the Microwave Zeeman Spectrum of Atomic Chlorine. George J. Wolga,* *Massachusetts Institute of Technology.*—Microwave magnetic resonance transitions corresponding to $\Delta M_J=\pm2$, $\Delta M_I=0$, that are forbidden in first order, have been observed in the $^2P_{\frac{3}{2}}$ ground state of both Cl^{35} and Cl^{37}. The secular determinant for the ground state of atomic chlorine was diagonalized on a digital computer and the energy levels expanded in a power series in $g_J\mu_0H/a$. The expected resonance magnetic fields at a given quantum energy for first- and second-order transitions are then obtained numerically. Interpretation of the resonances as arising from the absorption of two equienergetic photons is verified by the agreement between theory and experiment to within the experimental accuracy of 10 ppm. The power dependence of the observed spectrum and the differences in line intensities will be discussed. Finally, a simple, demountable, atom-producing and gas-handling apparatus will be described. This system has proven equally satisfactory for similar experiments with a variety of free atomic systems.

* Now at Cornell University.

F7. Nuclear Paramagnetic Spin-Spin Relaxation in CaF_2 and NaCl.* R. L. Strombotne and E. L. Hahn,† *University of California, Berkeley.*—When a system of magnetic nuclei in zero field is suddenly subjected to a magnetic field H_S on the order of magnitude of the internal local field H_L a magnetization M_Z appears which attains an equilibrium value in a time comparable to the high field spin-spin relaxation time T_2. This effect, nuclear paramagnetic spin-spin relaxation, has been observed in single crystals of NaCl and CaF_2 at room temperature by the following technique. The sample is prepolarized in a large field H_0 ($H_0\sim10$ kgauss) and then demagnetized adiabatically to zero field where H_S is applied. A second field H_B ($H_B>H_S, H_L$) is applied suddenly t_B sec later to inhibit further change in M_Z. The sample is returned adiabatically to H_0 where M_Z is measured by standard transient nuclear magnetic resonance techniques. The process is repeated. By varying t_B, the transient response of M_Z is found in any given field H_S. For $H_S \gtrsim 2H_L$, the transient response of M_Z consists of damped oscillations about the equilibrium value. The frequencies present in the oscillations are ω_0 and $2\omega_0$, where ω_0 is the Larmor frequency in H_S, $\omega_0=\gamma H_S$. The local field is defined as $H_L^2\,\mathrm{Tr}\{M_Z^2\}=\mathrm{Tr}\{\mathfrak{IC}_{dd}^2\}$.

* Work supported by the Office of Naval Research.
† Currently on leave at the Clarendon Laboratory, Oxford.

F8. NMR near Zero Field. An Extension of the Proton Magnetometer. DON D. THOMPSON AND R. J. S. BROWN, *California Research Corporation.*—Proton free-precession signals in magnetic fields as small as 8 mgauss have been observed in solutions of phosphorous acid. The signal arises from the hydrogen atom bonded directly to the phosphorus atom. The isotropic coupling constant is 659 sec^{-1}. The transition frequencies may be calculated from the Breit-Rabi formula. There are two perpendicular transitions and one which is parallel. The two perpendicular transitions are field dependent and were used to accurately measure magnetic fields down nearly to zero. The parallel transition has only second-order field dependence and is therefore not a sensitive field strength indicator. The signals were observed by producing population differences in the various states by applying a strong dc polarizing field and then suddenly removing it, receiving signals with appropriate coils. The use of this type system as a very low field magnetometer has some merit as the technique is simple and the measurement is absolute rather than relative. The method is also useful for measuring spin-spin couplings directly and very accurately.

F9. Multiple Resonances in Yttrium Iron Garnet Film. R. F. SOOHOO, *California Institute of Technology.*—Multi-peak resonances have been observed in a single crystal 0.0005 in. thick YIG disk cut parallel to the (110) plane. The observed absorption spectrum is interpreted in terms of spin wave resonances and the excitation of magnetostatic modes. Unlike the case of conducting Permalloy film, the effects due to eddy current and spin pinning by surface oxidation layers in YIG are negligible. Consequently, the origin of the surface anisotropy may be attributed solely to the lower order symmetry environment of the surface spins. The implication of our experimental results with regard to the validity of the exchange boundary condition, as well as the question of magnetostatic mode excitation, will be discussed.

WEDNESDAY AFTERNOON AT 2:00

Franz 104

(D. J. PROWSE presiding)

High-Energy Nuclear Physics I

G1. Isobar Mechanism for Pion-Baryon Higher Resonances.* S. F. TUAN, *Brown University.*—Peierls' isobar mechanism is extended to pion-hyperon interactions on the assumption that Y_1^* is the $\pi\Lambda$ isobar whose mass lies below the $\bar{K}N$ threshold and of spin parity P_1. It is shown that this mechanism when *combined* with experimental data currently available, does suggest that a pion-hyperon resonance in the $I=1$ channel at c.m. energy 1645 Mev with spin-parity assignment D_1 is possible. This resonance state is expected to reflect in the total K^--p and K^--n (pure $I=1$) cross sections as resonance peaks centered at around 685 Mev/c K-meson lab momentum. Experimental implications of this isobar model for pion-baryon interactions as well as certain mathematical difficulties associated with the over-all validity of such a mechanism are also discussed.

* Work supported in part by the U. S. Atomic Energy Commission.
[1] R. F. Peierls, Phys. Rev. Letters 6, 641 (1961).

G2. Pion Hyperon Resonances and Global Symmetry.* GORDON L. SHAW, *University of California, La Jolla,* AND MARC H. ROSS, *Indiana University.*—An effective range solution of S-wave K^-p data is presented which yields the Y_0^*, $I=0$ $\pi\Sigma$ resonance at 1405 Mev, as quasi bound state of $\bar{K}N$ system, and has the weak $J=\frac{1}{2}$ K matrix elements $\mathbf{K}_{yy'}$ (which would describe πY scattering in the absence of coupling to $\bar{K}N$ channel) given by global symmetry of the pion-baryon interactions. The actual $K_{yy'}$, determined by the nonperturbative "uncoupled phase procedure,"[1] are largely modified from the $\mathbf{K}_{yy'}$ for the S wave $\bar{K}N$ system. These results lend support to a simple description of the πY resonances: The Y_1^*, $\pi\Lambda$ resonance at 1385 Mev, and Y_0^*, πY resonance recently observed at 1580 Mev,[2] are global symmetry resonances analogous to $J=\frac{3}{2}$, $I=\frac{3}{2}$ πN resonance,[3] and Y_0^* is quasi bound state of S wave $\bar{K}N$ system.

* Supported in part by the U. S. Atomic Energy Commission.
[1] M. Ross and G. Shaw, Ann. Phys. 9, 391 (1960).
[2] Lundby, Dowell, Leontic, Meunier, Stroot, and Szeptycka (private communication from B. Leontic).
[3] D. Amati, B. Vitale, A. Stanghellini, Phys. Rev. Letters 5, 520 (1960). T. Lee and C. Yang, Phys. Rev. 122 1954 (1961).

G3. Summing the Perturbation Series for Pion-Pion Interaction. TAI TSUN WU, *Harvard University.*—The problem of the pion-pion scattering is studied on the basis of the model of a four-particle direct interaction without derivative coupling. Renormalization is carried out for this model with a detailed analysis of overlap insertions. To every finite order in the renormalized coupling constant, it is shown that the unitarity relation holds and that the Feynman integral representation is still valid, and hence renormalization has no effect on analytic properties. By considering only Feynman graphs with two-pion intermediate states, possible procedures for obtaining approximate integral equations for the elastic matrix elements are discussed, where crossing symmetry is exactly preserved and unitarity is satisfied up to the production threshold.

G4. An Analysis of the Decay Characteristics of about 1000 Negative Tau Mesons.* L. SMITH AND D. J. PROWSE, *University of California, Los Angeles.*—About 1000 negative tau-meson decays in flight have been found in the LRL 15-in. bubble chamber filled with deuterium and exposed to K^--meson beams of various momenta. The distribution of the events on the Dalitz plot is almost isotropic, reflecting the zero spin of the K meson. The deviations from isotropy follow the same trend as was found for the positive tau-meson decay.[1] The data is being examined for possible π-π interaction effects and as a possible test of the $\Delta T=\frac{1}{2}$ rule.[2]

* Partially supported by the U. S. Atomic Energy Commission.
[1] McKenna, Natali, O'Connel, Tietge, and Varshneya, Nuovo cimento 10, 763 (1958).
[2] See, for example, S. Weinberg, Phys. Rev. Letters 4, 87 (1960).

G5. Pion-Pion Correlation in Tau Decay.* THOMAS A. O'HALLORAN, GERSON GOLDHABER, AND SULAMITH GOLDHABER, *Lawrence Radiation Laboratory and University of California, Berkeley.*—We have investigated pion-pion correlations in approximately 3000 tau decays. Deviations of the π^+ and π^- energy spectra and angular distributions from those predicted using the Lorentz invariant phase space have been observed.[1] The data will be discussed in terms of final-state pion-pion interaction. A search for anomalous tau-meson decay modes has yielded to date one event decaying according to $\tau^+ \to \pi^+ + \pi^+ + \pi^- + \gamma$. It is interesting to note that the γ-ray

energy, $E_\gamma = 32.6 \pm 1.0$ Mev, coincides within the quoted error with the only other known example of a radiative τ decay.[2,3]

* This work was done under the auspices of the U. S. Atomic Energy Commission.

[1] S. McKenna, S. Natali, M. O'Connell, J. Tietze, and N. C. Varshneya, Nuovo cimento **10**, 763 (1958).
[2] R. R. Daniel and Y. Pal, Proc. Indian Acad. Sci. **40**, 114 (1954).
[3] R. H. Dalitz, Phys. Rev. **99**, 915 (1955).

G6. Formation of the 1385-Mev Y^*-Excited State in the Interactions of K^- Mesons with Neutrons.* M. TAHER-ZADEH, D. J. PROWSE, D. H. STORK, AND H. K. TICHO, *University of California, Los Angeles.*—The ratios of the cross sections for the reactions, $K^- + n \rightarrow Y^{*0} + \pi^0$, $K^- + p \rightarrow Y^{*\pm} + \pi^\mp$, have been measured at 600 Mev/c, 765 Mev/c, and at 865 Mev/c. An analysis by Dalitz and Miller[1] of the experimental results on the $K^- + p$ reaction obtained by Berge *et al.*[2] suggested that there was a dominant I spin state of the $K^- + p$ system involved. The above ratio should be equal to 2 or 0 for the pure $I = 1$ or 0 channel, respectively. Our result at 765 Mev/c is 1.4 ± 0.3 indicating a dominant $I = 1$ channel. The ratio at 600 Mev/c is consistent with 1 and the result at 965 Mev/c consistent with 2; it thus can be inferred that the $I = 0$ cross section is falling with energy in this momentum range.

* Partially supported by the U. S. Atomic Energy Commission.
[1] R. H. Dalitz and D. H. Miller, Phys. Rev. Letters **6**, 562 (1961).
[2] J. P. Berge, P. Bastien, O. Dahl, M. Ferro-Luzzi, J. Kirz, D. H. Miller, J. J. Murray, A. H. Rosenfeld, R. D. Tripp, and M. B. Watson, Phys. Rev. Letters **6**, 557 (1961).

G7. Production of Pions by Positive K Mesons.* H. F. FISK, W. S. SLATER, D. H. STORK, AND H. K. TICHO, *University of California, Los Angeles,* AND WILLIAM CHINOWSKY, GERSON GOLDHABER, AND SULAMITH GOLDHABER, *University of California, Berkeley.*—A total of 210 events of the type $K^+ + N \rightarrow K + N + \pi$ (N = nucleon) have been analyzed from an exposure of the LRL 15-in. hydrogen-deuterium bubble chamber to a separated K^+ beam at momenta of 810 and 642 Mev/c. Most of the data has been obtained at 810 Mev/c, where the K^+p cross sections are 0.72 ± 0.07, 0.25 ± 0.05, 0.10 ± 0.03 mb for $K^0 p \pi^+$, $K^+ p \pi^0$, and $K^+ n \pi^+$ production states, respectively. These numbers are consistent with production with either a dominant $T_{N\pi} = \frac{3}{2}$ state or a dominant $T_{K\pi} = \frac{1}{2}$ state. For K^+n we obtain 0.51 ± 0.09, 0.30 ± 0.15, and 0.25 ± 0.15 for $K^+ p \pi^-$, $K^0 n \pi^+$, and $K^0 p \pi^0$. Inequalities required by charge independence are satisfied. Significant production in the total I-spin $T = 0$ state is implied by a comparison of the K^+n data with K^+p. The dominant production states are $K^+ p \pi^-$ (55 events) and $K^0 p \pi^+$ (93 events). The $K^+ p \pi^-$ shows a significant forward K and backward p peaking while the $K^0 p \pi^+$ shows a less marked forward K and backward p distribution and could be isotropic. The analysis of angular and momentum distributions is continuing and will be reported.

* Partially supported by the U. S. Atomic Energy Commission.

G8. $\Sigma^- \theta^0 / Y^0 \theta^0$ Ratio from 1.3-Bev π^- on Carbon.* L. SEIDLITZ AND C. R. SUN, *Princeton University.*—Cloud-chamber experiments[1] on the production of hyperons in complex nuclei show a surprisingly low Σ^-/Λ^0 ratio. This ratio may reflect on hyperon-nucleon interactions and on nucleon-nucleon correlations. To improve the detection efficiency, a redetermination with bubble-chamber observations has been made. Pictures obtained by the Columbia group[2] in a propane chamber were examined. A large background of spurious events was drastically reduced by requiring that each possible Σ^- be accompanied by an identified θ^0. Seven possible $\Sigma^- \theta^0$ events have been found, yielding a preliminary upper limit 0.11 ± 0.05 for the ratio $\Sigma^- \theta^0 / Y^0 \theta^0$ as compared to 0.36 ± 0.11 expected from elementary cross sections. Attributing this difference solely to charge exchange, the lower limit on the fraction of Σ^- exchanging is 0.63 ± 0.19, implying a charge-exchange cross section > 72 mb.

* Supported by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] T. Bowen, J. Hardy, Jr., G. Reynolds, C. R. Sun, G. Tagliaferri, O. E. Werbrouck, and W. H. Moore, Phys. Rev. **119**, 2030 (1960).
[2] F. Eisler *et al.*, Nuovo cimento **10**, 468 (1958).

G9. $K^+ + d$ Noncharge Exchange Scattering at 377 Mev/c.* W. E. SLATER AND V. J. STENGER, *University of California, Los Angeles* (introduced by H. K. Ticho).—Preliminary results on the reaction $K^+ + n \rightarrow K^+ + n$ inferred from $K^+ + d \rightarrow K^+ + n + p$ at 377 Mev/c incident momentum will be reported. These events have been studied in the Lawrence Radiation Laboratory 15-in. deuterium bubble chamber. They are separated from a considerable background of K^+ decays and $K^+ + d \rightarrow K^0 + p + p$ events by means of ionization measurements on the secondary tracks. This measurement consists of superimposing on a questionable track a slit of adjustable curvature, intensity (I), and width, and adjusting for extinction. Although limited in accuracy ($\Delta I / I = 9\%$), this method is quick and is applicable to tracks on which other types of ionization measurements such as bubble counting are impossible. About 90% of events kinematically ambiguous between $K^+ + d \rightarrow K^+ + p + n$ and $K^+ + d \rightarrow K^0 + p + p$ are resolvable.

* Partially supported by the U. S. Atomic Energy Commission.

THURSDAY MORNING AT 9:30

Chemistry 2250

(BYON T. WRIGHT presiding)

Accelerators

Invited Papers

H1. Preliminary Operation of the UCLA Spiral-Ridge Cyclotron. J. REGINALD RICHARDSON, *University of California, Los Angeles.* (30 min.)

H2. Berkeley 88-In. Cyclotron. ELMER L. KELLY, *Lawrence Radiation Laboratory, University of California, Berkeley.* (30 min.)

H3. Analog of an Isochronous Cyclotron with Energy M_0c^2. R. S. LIVINGSTON, *Oak Ridge National Laboratory.* (30 min.)

H4. Stanford Two-Mile Linear Electron Accelerator. ROBERT F. MOZLEY, *Stanford University.* (30 min.)

H5. Ultra-High Energy Proton Synchrotrons. MATTHEW SANDS, *California Institute of Technology.* (30 min.)

THURSDAY MORNING AT 10:00

Chemistry 2224

(J. R. HOLMES presiding)

Solid State II

I1. Stimulated Optical Emission in Ruby from 4.2° to 300°K: Zero Field Splitting and Mode Structure.* I. J. D'HAENENS AND C. K. ASAWA, *Hughes Research Laboratories.*—The spectral character of the stimulated emission from ruby has been investigated; we find that the zero field splitting (0.38 cm^{-1}) of the $^4A_2$ ground level and the cavity length d, determine the spectral character of this emission. At 300°K the $\bar{E}(^2E) \rightarrow {}^4A_2(\pm\frac{3}{2})$ transition, which has higher transition probability than the $\bar{E}(^2E) \rightarrow {}^4A_2(\pm\frac{1}{2})$ transition, is induced into oscillation in about eight modes separated by $\Delta\bar{\nu} = (2dn_\omega\ cm)^{-1}$, where n_ω is the index of refraction for the ordinary ray. The extremely fast T_1 relaxation between the $(\pm\frac{3}{2}) \rightarrow (\pm\frac{1}{2})$ ground levels prevents the oscillation of the $\bar{E}(^2E) \rightarrow {}^4A_2(\pm\frac{1}{2})$ transition at this temperature. At ≅80°K, where T_1 has lengthened appreciably, both transitions are identified in the stimulated emission spectrum; each oscillates in a cavity mode plus a "traveling wave" mode. At 4.2°K the system oscillates in the traveling wave modes, unless the length of the cavity d is such that it has resonances coincident with the transition frequencies.

* This work was supported in part by the U. S. Air Force, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

I2. Optical Maser Action in the R_2 Line in Ruby. F. J. MCCLUNG AND S. E. SCHWARZ, *Hughes Research Laboratories,* F. J. MEYERS, *Hughes Aircraft Company,* AND R. W. HELLWARTH AND I. J. D'HAENENS, *Hughes Research Laboratories.*—Optical maser action has been observed at the R_2 line in ruby. Because of a fast thermal relaxation between the two ^2E levels, it is not usually possible to satisfy the maser conditions at R_2 when R_1 is masering. However, if the R_1 line can be suppressed from masering even at high inversions, the R_2 line can be made to maser by the appropriate selection of operating conditions. This has been accomplished by using, for end plates, multilayer dielectric interference filters which have high transmission at R_1 and low transmission at R_2. The necessary filter conditions and the operating characteristics will be described.

I3. Nonlinear Optical Effects. RUBIN BRAUNSTEIN, *RCA Laboratories.*—The theory of multiple-photon excitation of an electron from the valence to the conduction in a solid is developed. It is shown that this process exhibits an intensity dependent absorption edge at photon energies below the minimal energy gap of a solid. The experimental conditions for observing such transitions are considered; presently available optical maser sources of radiation are of sufficient intensity to enable double-quanta processes to be experimentally observable in semiconductors and insulators. A number of possible nonlinear light effects in solids are discussed where the optical properties of a medium depend upon the value of the incident E- and H-radiation field; as a consequence of the nonlinear properties of these effects and their intrinsic fast response times, the possibility exists of producing harmonic generation and mixing at infrared and visible frequencies.

I4. Correlation Spectroscopy with a Flickering Source. R. M. RHODES AND K. J. STETTEN, *Melpar, Inc.* (introduced by M. R. Kagan).—The effects of low-frequency source flicker are examined at small modulation efficiencies on instruments which convert optical to lower frequencies. These instruments yield a time function which may be analyzed by Fourier transform to determine an optical spectrum. Low-frequency flicker will pass through these instruments distorting the obtained spectrum. A method is found for correction of the output spectrum when the flicker function has been independently determined.

I5. High-Field Studies of the Ferromagnetic-Antiferromagnetic Exchange Inversion in $Mn_{2-x}SbCr_x$. WARREN E. HENRY AND VICTOR J. KING, *Lockheed Research Laboratory.*—An experimental investigation has been carried out on the magnetization of metallic crystals of $Mn_{2-x}SbCr_x$ in magnetic fields up to 95 000 gauss. Values of X up to 0.1 have been used. A saturation magnetization was measured and fits the Néel prediction. Saturation is nearly complete at 70 000 gauss above the transition range. For the mid-transition range the magnetization is linear in low fields (10 000 to 40 000 gauss). $(\partial M/\partial H)_T$ is 10^{-6} Bohr magnetons per molecule per gauss. Apparent molecular fields range from a strongly ferromagnetic exchange field of about 3 000 000 gauss to a slightly antiferromagnetic exchange field in the middle of the inverse transition to a strongly antiferromagnetic apparent molecular field of about 500 000 gauss below the transition. The pattern of experimental results fits the Kittel theory of two separate exchange interactions one exchange changing sign in the middle of the transition. The data would also fit a single exchange function which passes through zero.

I6. Magnon Thermal Conductivity of Yttrium Iron Garnet (YIG).* R. L. DOUGLASS, *University of California, Berkeley* (introduced by C. Kittel).—Two single crystals of YIG have been investigated at temperatures $0.4° \leq T \leq 4.2°K$ and magnetic fields $0 \leq B \leq 20\,000$ gauss. Temperature dependences of zero field thermal conductivities were T^{n_i}, where $1.7 < n_1 < 2.1$ and $1.4 < n_2 < 2.3$ with lower exponents at lower temperature. Near 1°K in zero field the conductivities were $K_1 = 0.017^{n_1}$ and $K_2 = 0.003T^{1.8}$ w/cm °K. A field of 500 gauss had little effect on K_1 (0.5°K) but increased K_2 (0.5°K) by 30%. A field of 20 000 gauss decreased K_1 (0.5°) and K_2 (0.5°) by 67 and 65%, respectively. Field effects were smaller at higher temperatures. No significant change in field or temperature dependence was observed upon reducing the thickness of the second sample from 0.16 to 0.055 cm. These results are interpreted as evidence that most of the heat at low temperatures is carried by magnons, which are scattered by imperfections and ferromagnetic domain boundaries. If magnon relaxation length is independent of wavelength, this model predicts T^3 temperature dependence. The observed conductivities at 0.5°K correspond to magnon relaxation lengths of $\lambda_1 = 0.02$ cm and $\lambda_2 = 0.007$ cm. Similar results have been reported by B. Luthi.[1]

* This work was supported by the National Science Foundation.
[1] B. Luthi, J. Phys. Chem. Solids (to be published).

I7. de Haas-van Alphen Effect in Rubidium.* A. C. THORSEN AND T. G. BERLINCOURT, *Atomics International.*—The de Haas-van Alphen effect has been observed in a single crystal of rubidium in pulsed magnetic fields up to 160 kgauss. Preliminary measurements of the period of the susceptibility oscillations in the one crystallographic orientation thus far investigated yield an extremal cross sectional area of the Fermi

surface in fair agreement with that predicted by the free electron theory.

* Supported by the U. S. Atomic Energy Commission.

I8. Adsorption of Hydrogen on Solidified-Gas Films,* ANGUS L. HUNT, CLYDE E. TAYLOR, AND JOHN E. OMOHUNDRO, *Lawrence Radiation Laboratory.*—It has been found that hydrogen is rapidly adsorbed at 11°K on solidified-gas films of Ar, N_2, O_2, H_2O, N_2O, and CO_2. From hydrogen pumping speed measurements in the 10^{-9} mm Hg pressure range on solidified-gas substrates of geometrical area 3×10^3 cm² to 5×10^3 cm², it is estimated that the initial sticking probabilities for room-temperature hydrogen are between 0.1 and 1.0 for coverages to about one monolayer, depending on the composition of the solidified-gas substrate. Most of the adsorbed hydrogen is desorbed between the hydrogen critical temperature and the normal boiling temperature. The adsorption energies are estimated to be several hundred calories per mol if calculated from an assumed monolayer surface density of 10^{15} molecules per cm² in a simple mobile monolayer adsorption theory. It was also found that helium is not adsorbed in comparable quantities on the solidified-gas substrate at 11°K. The results indicate that adsorption cryo-pumping of hydrogen in practical quantities is feasible.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

THURSDAY MORNING AT 10:00

Chemistry 2276

(R. MARRUS presiding)

Resonance Physics II

J1. Paramagnetic Relaxation of Nd^{3+} and Ce^{3+} in Lanthanum Magnesium Nitrate at Low Temperatures; Observation of the Phonon Bottleneck.* R. H. RUBY, H. BENOIT,† P. L. SCOTT, AND C. D. JEFFRIES, *University of California, Berkeley.*—By observing transient recovery of microwave paramagnetic resonance signals at $\nu=9.6$ kMc we measure the spin-lattice relaxation time T_1 of Nd^{3+} in the crystal $La_2Mg_3(NO_3)_{12}\cdot24H_2O$ in the range $T=4.2°$ to 0.3°K, the lower temperatures being obtained by adiabatic demagnetization. For crystals containing 1 or 5% Nd and oriented $z\perp H$, the results are $T_1^{-1}=6.3\times10^9\exp(-47/T)+0.3\coth(h\nu/2kT)$ sec^{-1}. The first term represents Orbach's process,[1] which we estimate from Judd's[2] wave functions for Nd^{3+} in this crystal to be $T_{10}^{-1}\approx2\times10^{10}\exp(-47.6/T)$. The second term is the direct process, which we calculate to be $T_{1d}^{-1}\approx0.6\coth(h\nu/2kT)$. At low temperatures T_{1d}^{-1} tends toward a constant, corresponding to spontaneous emission of phonons; we observe this. For a 2% Ce crystal we observe $T_1^{-1}\approx5\times10^9\exp(-34/T)+0.8[\coth(h\nu/2kT)]^2$ sec^{-1}. The second term, observed at temperatures below 1°K, can be shown to represent the observed relaxation rate when the true direct relaxation rate is so rapid that the phonons cannot carry the excitation to the bath rapidly enough and become "hot."

* Supported by U. S. Atomic Energy Commission and Office of Naval Research.
† NATO Fellow.
[1] C. B. P. Finn, R. Orbach, and W. P. Wolf, Proc. Phys. Soc. (London) **77**, 261 (1961).
[2] B. R. Judd, Proc. Roy. Soc. (London) **A232**, 458 (1955).

J2. Ground State Splitting of d^5 Ions in Noncubic Crystalline Fields. JACK S. MARGOLIS, *Atomics International.*—The ground state of the free ions Mn^{2+} and Fe^{3+} is orbitally nondegenerate but does exhibit a sixfold spin degeneracy. In a crystalline environment this spin degeneracy is lifted to some extent; the resultant splitting is generally a small fraction of a cm^{-1}. In order to explain this splitting, the theory of the spin-orbit interaction in a noncentral field has been worked out and applied to a calculation of the splitting of the ground state of these ions. The interaction is taken to be

$$H'=\frac{e\hbar}{2m^2c^2}\sum_i \mathbf{S}_i\cdot[\mathbf{E}_i\times\mathbf{p}_i].$$

Second-order perturbation theory is required to achieve a splitting of the ${}^6S_{\frac{5}{2}}$ ground state; however, only one excited state and the $Y_{2,\pm2}$ $Y_{2,0}$ terms in the potential enter into the calculations. The observed splittings of Mn^{2+} and Fe^{3+} in Tutton salts, LiCl:Mn, Beryl, and $AlCl_3\cdot6H_2O$ are calculated.

J3. Quadrupole Coupling in Europium Ethylsulfate.* D. A. SHIRLEY AND C. A. LOVEJOY, *Lawrence Radiation Laboratory and Department of Chemistry, University of California, Berkeley.*—In 1957 Elliott[1] proposed an NMR experiment on europium ethylsulfate and showed that the Hamiltonian of the lowest (singlet) state should contain a quadrupole term due to an admixture, through the crystal field term V_2^0, of the singlet $|J=2, J_z=0\rangle$. We have observed a quadrupole interaction of approximately the expected magnitude, but of different sign, in nuclear alignment experiments on Eu^{152} and Eu^{154} in a lattice of neodymium ethylsulfate. At 0.02°K anisotropies of $+0.080\pm0.005$ and $+0.094\pm0.005$ were observed for the 1.42-Mev γ ray of Sm^{152} and the 1.28-Mev γ ray of Gd^{154}, respectively. A $1/T$ temperature dependence characteristic was observed. Comparison of the signs of these anisotropies with that of the 0.344-Mev γ ray of Gd^{155} ($\epsilon\cong+0.06\pm0.01$) establishes the spin of the 1531 kev level of Sm^{155} and of the 1400-kev level of Gd^{154} as 2. If we assume the ground states of Eu^{153} and Eu^{154} have negative parity, we may derive quadrupole coupling constants $P_{153}=-0.61\pm0.04\times10^{-3}$ cm^{-1} and $P_{154}=-0.72\pm0.04\times10^{-3}$ cm^{-1}. Combining an estimated intrinsic quadrupole moment of +7 barns with reference 1, we would calculate $P=+0.23\times10^{-3}$ cm^{-1}. Thus there is a sign discrepancy in the quadrupole coupling constant.

* Work supported by the U. S. Atomic Energy Commission.
[1] R. J. Elliott, Proc. Phys. Soc. (London) **70B**, 119 (1957).

J4. Sign of Electron-Nuclear Interaction of *F*-Center Electrons in KCl. W. E. BLUMBERG, *Bell Telephone Laboratories, Inc.*—By measuring the amplitude of ENDOR[1] transitions of the nearest neighbor K ions as a function of the location of the microwave pumping frequency in the inhomogeneously broadened *F*-center spin resonance line at low temperatures the sign of the electric quadrupole interaction constant Q' has been determined to be positive. From the splitting[2] attributed to the spin-spin coupling of nuclei on opposite sides of the vacancy the product of Q' and the isotropic hyperfine interaction constant A is seen to be positive. Thus A itself is positive. It has been determined previously[1] that A and B, the anisotropic hyperfine interaction constant, are of the same

sign, and thus B is also positive. The sign of all these constants is in agreement with previous calculations.[3]

[1] G. Feher, Phys. Rev. 105, 1122 (1957).
[2] W. E. Blumberg and G. Feher, Bull. Am. Phys. Soc. 5, 183 (1960).
[3] W. E. Blumberg and T. P. Das, Phys. Rev. 110, 647 (1958).

J5. Electron Spin Resonance Studies of the Cyclooctatetraenyl Anions.* H. L. STRAUSS,† T. J. KATZ, AND G. K. FRAENKEL, *Columbia University.*—The ESR spectrum of the cyclooctatetraenyl radical[1] has been studied in dimethoxyethane and tetrahydrofuran using Li, Na, and K as reducing agents. The spectra are interpreted by assuming varying concentrations of ion pairs which contribute alkali metal hyperfine structure, and radical species which do not. The parameters which characterize the spectrum of the uncomplexed radical are: hydrogen splitting 3.209 ± 0.007 gauss; carbon-13 splitting 1.28 ± 0.03 gauss; $g=2.0025\pm0.0001$; minimum linewidth 0.17 gauss; $T_1\approx T_2$. The disproportionation constant of the radical is about 5×10^8. This leads to an estimate of about 56 kcal/mole for the compression energy. The relative rates of electron exchange among the anions were found to depend strongly on the alkali metal and the solvent. The conflicting evidence concerning the planarity of the radical will be discussed.

* Supported in part by the U. S. Air Force through the Office of Scientific Research.
† Present address: Department of Chemistry, University of California, Berkeley.
[1] T. J. Katz and H. L. Strauss, J. Chem. Phys. 32, 1873 (1960).

J6. The Kingdon Cage as a Molecular Beam Detector.* P. R. BROOKS† AND D. R. HERSCHBACH, *University of California, Berkeley.*—Studies of molecular beam scattering at thermal energies have mostly been confined to beams of alkali metals and their compounds, since these can be readily detected by surface ionization. In order to carry out measurements of collision cross sections for other molecules, we have developed a Kingdon Cage or space-charge detector, similar to that of Estermann and Stern.[1] The beam is directed into the diode cage and ionized by a space-charge limited electron current. The positive ions trapped within the cage are extremely effective in neutralizing the space charge and thus produce a large increase in plate current. In the case of a methyl iodide beam, it is found that about 10^5 electrons are released for each beam molecule which enters the diode. The application of the detector to measurements of total cross sections for collisions of alkyl halide beams with various gases is discussed. For many of these molecules (unlike the alkalies) intermolecular potential constants derived from transport properties or virial coefficient data can be compared with those obtained from beam scattering.

* Supported by the Atomic Energy Commission and the Alfred P. Sloan Foundation.
† National Science Foundation Predoctoral Fellow.
[1] I. Estermann and O. Stern, Z. Physik 85, 135 (1933).

J7. Precision Measurements of hfs of Stable Rb Isotopes by Atomic Beams.* S. PENSELIN,† T. MORAN, AND V. W. COHEN, *Brookhaven National Laboratory,* AND G. WINKLER, *U. S. Signal Corps.*—A number of precision measurements were made on the hfs of the ground state of Rb^{85} and Rb^{87} using a "flop-in" type of magnetic resonance apparatus. An oscillatory field separation of 19.5 cm and a highly homogeneous magnetic field permitted the observation of resonance lines approximately 1.3 kc wide. The frequency control system, based on an Atomichron, had a synthesizer capable of varying the operating frequency in increments as small as frequency 1 cps. In order to neutralize effects of phase shift between oscillatory field loops the entire loop system could be rotated about 180°. The determination of $\Delta\nu$ was made from the $(F,0)\leftrightarrow(F',0)$ transitions giving the values $\Delta\nu_{85}=3\,035\,732\,439\pm5$ cps and $\Delta\nu_{87}=6\,834\,682\,614\pm3$ cps. This agrees with measurements by Essen *et al.* and Bender *et al.* The magnetic moment of Rb^{85} was determined from the doublet $(3,-1)\leftrightarrow(2,-2)$, and $(3,-2)\leftrightarrow(2,-1)$ for which the frequency difference is $2g_J\mu_0H$. The field was taken near a point, where the frequency has a minimum. Assuming a value of g_J of 2.002409 (27) we compute a value of $\mu=1.34821$ (5) nm and, correcting for diamagnetic shielding, we get 1.35270 (25) nm. The value of the mean frequency of the doublet, 2 611 882 320±20 cps agrees with that calculated from the Breit-Rabi formula to within one part in 10^8.

* Work performed under the auspices of the Atomic Energy Commission.
† On leave from the University of Heidelberg.

J8. Nuclear Spin of Au^{196m}.* Y. W. CHAN, W. B. EWBANK, W. A. NIERENBERG, AND H. A. SHUGART, *University of California and Lawrence Radiation Laboratory, Berkeley.*—Atomic beam measurements on the 9.5-hr isomer of Au^{196} in its $^2S_{\frac{1}{2}}$ electronic ground state show that the nuclear spin is $I=12$. An atomic-beam magnetic-resonance apparatus of the flop-in type was used to observe $\Delta F=0$ transitions at several magnetic fields up to 17 gauss. The gold used in these measurements was produced by alpha-bombardment of natural platinum foil in the Crocker 60-in. cyclotron. Standard chemical procedures were used to prepare the gold in pure metallic form. Half-life measurements were used to identify the isotope that contributed to the resonances. Recent studies[1,2] of the decay scheme of 9.5-hr Au^{196m} have indicated that the nuclear spin of this isomer should be very large. A prediction of $I=11$ has been made by two such studies, based on electron conversion ratios for the isomeric transition.

* This research work was supported by the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] R. Van Lieshout, R. K. Girgis, R. A. Ricci, A. H. Wapstra, and C. Ythier, Physica 25, 703 (1959).
[2] T. M. Kavanagh, Can. J. Phys. 38, 1436 (1960).

J9. Nuclear Spin of Ag^{113}.* W. B. EWBANK, Y. W. CHAN, AND H. A. SHUGART, *Univesity of California and Lawrence Radiation Laboratory, Berkeley.*—The atomic-beam magnetic resonance method has been used to measure the nuclear spin of 3.2-hr Ag^{113}. All measurements were made in the $^2S_{\frac{1}{2}}$ electronic ground state of silver. A spin search at low magnetic field has indicated that the nuclear spin is 2 which was confirmed later by observation of resonances of the $(\frac{1}{2},-\frac{1}{2})\leftrightarrow(\frac{1}{2},-\frac{1}{2})$ "flop-in" transition at higher magnetic fields. Resonances corresponding to the transitions $\Delta F=\pm1$, $\Delta M_F=0,\pm1$ also have been observed at low magnetic field and give preliminary values for the hyperfine structure. The radioactive isotope was produced from natural palladium metal by the (α,pn)reaction with 48-Mev α particles from the Crocker 60-in. cyclotron. The metallic silver sample was separated chemically from the palladium target.

* This research work was supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

J10. Nuclear Spin of Holmium-161.* BURTON BUDICK† AND RICHARD MARRUS, *Lawrence Radiation Laboratory and University of California, Berkeley.*—The nuclear spin of holmium-161 has been measured as 7/2 by the method of atomic beams. In addition, the ground state electronic angular momentum J is established as 15/2 which very probably arises from the Hund's rule term ^4I of the configuration $(4f)^{11}(6s)^2$. Production of the holmium is by a p-n reaction on dysprosium at the Berkeley 60-in. cyclotron. Beams are produced by direct vaporization from the dysprosium metal. The holmium is detected by counting electrons from the radioactive decay. The isotope is unambiguously identified as holmium-161 on the basis of the method of production, the measured g_J and J values, and the measured half-life of 2.5 hr.

* This research was sponsored by the U. S. Atomic Energy Commission.
† Abraham Rosenberg Research fellow.

J11. Nuclear Spin of Yttrium-91.* F. R. PETERSEN AND H. A. SHUGART, *University of California, Berkeley.*—The nuclear spin $I=\frac{1}{2}$ for 58-day yttrium-91 has been measured by the atomic-beam magnetic-resonance method. Five resonances in the $^2D_{\frac{3}{2}}$ electronic ground state corresponding to the transition $(2, 1 \leftrightarrow 2, 0)$ have been observed up to a field of 200 gauss. These resonances establish the spin of this isotope and provide preliminary information concerning its hyperfine structure and magnetic moment. The isotope was obtained from Oak Ridge National Laboratories as an aqueous solution of YCl_3. Anhydrous YCl_3 was reduced to yttrium metal with calcium filings prior to forming the yttrium beam. Identification and purity of the sample were checked by decay analysis. Resonance detection was accomplished by collecting the radioactive atoms on sulfur-coated "buttons" which were later counted in continuous-flow beta-counters. The observed spin is the same as for stable Y^{89}.

* Supported in part by the U. S. Air Force Office of Scientific Research and the U. S. Atomic Energy Commission.

THURSDAY MORNING AT 10:00

Franz 104

(C. FRONSDAL presiding)

Theoretical Physics

K1. A Discrepancy in the Hyperfine Structure of Hydrogen. DANIEL E. ZWANZIGER.* *University of California, Berkeley.*—Because of a reported discrepancy of 34 ± 21 parts per million between measured and calculated values of the hyperfine separation of the ground state of atomic hydrogen, the next higher order radiative corrections beyond the previously calculated order of α^2 hfs were investigated. Besides the expected presence of corrections of order $\alpha^3 \ln\alpha$ hfs, a larger correction of order $\alpha^3 \ln^2\alpha$ hfs was found. The calculation of the level shift of both of these logarithmic orders has been completed yielding results which agree with those of Layzer. In the case of hydrogen the numerical contribution is -9.28 ppm. When this is combined with previous results, the discrepancy between measured and calculated values is increased to 43 ± 21 ppm. The uncertainty is due largely to the uncertainty in the value of α, which is obtained from fine structure measurements, and which appears in the theoretical formula for the hyperfine separation. Possible explanations of the discrepancy, which now seems definitely established, are considered: an inaccuracy in the accepted value of the fine structure constant, or an inadequate evaluation of the polarization diagram in which one or more pi-mesons are present in an intermediate state.

* National Science Foundation post-doctoral Fellow.

K2. Logarithmic Corrections to Hyperfine Shift in Hydrogenic Atoms. A. J. LAYZER,* *Institute of Mathematical Sciences, N. Y. U.*—A calculation has been made of the $\alpha^3 \ln^2\alpha$ and $\alpha^3 \ln\alpha$ corrections to the hyperfine shift in hydrogenic atoms. The result agrees with that of Zwanziger. We used the method of the free propagator expansion, as in the previous evaluation of similar Lamb shift terms. Just as in the Lamb shift case, one finds that due to the nonanalytic nature, as a function of $w \equiv (\alpha Z)^2$, of the present logarithmic corrections, only the first few terms of the expansion are required for the calculation.

* Work supported in part by the U. S. Atomic Energy Commission.

K3. (Abstract withdrawn.)

K4. High-Frequency Region of the Bremsstrahlung Spectrum.* R. J. JABBUR AND R. H. PRATT, *Stanford University.*—Special techniques are required to calculate the cross section σ_{tip} for a bremsstrahlung process in which most of the energy of the incident electron is transferred to the photon. Fano noted that this process is closely related to atomic photoeffect, and it has since been shown that, neglecting contributions to the cross section of relative order $\alpha^2 \equiv (Z\alpha)^2$, σ_{tip} can be obtained from the photoeffect cross section σ_K.[1] A more accurate calculation for the high-energy limit of σ_K is now available.[2] In the present work similar techniques are used to obtain the cross section σ_{tip} from high-energy electrons, neglecting only relative order α^4. This requires a summation over final s and p electrons, but neglects d, f, etc., states. Results will be compared with the recent experiments of Hall and Hanson.[3] Applications to photoeffect and pair production will be noted.

* Research supported by the U. S. Air Force Office of Scientific Research.
[1] R. H. Pratt, Phys. Rev. **120**, 1717 (1960).
[2] R. H. Pratt, Phys. Rev. **117**, 1017 (1960).
[3] H. E. Hall and A. O. Hanson (to be published).

K5. Conserved Vector Current Theory and Nuclear Matrix Elements in Beta Decays of B^{12} and N^{12}. M. MORITA, *Columbia University.*—A recent experiment[1] shows that the beta ray spectra for B^{12} and N^{12} strongly favor the theory of conserved vector current by Feynman and Gell-Mann. In fact, the effect which has been observed in experiment as the energy dependence of the ratio of electron and positron spectra agrees quite well with the theoretical prediction. However, one question remains. That is, in experimental data the energy dependence of the correction factor for the electron is about twice as large as the theoretical value, while that for the positron is zero. One answer to this question is that the second forbidden coordinate type matrix elements $\mathfrak{M}(\boldsymbol{\sigma} r^2)$ and $\mathfrak{M}[(\boldsymbol{\sigma}\cdot\mathbf{r})\mathbf{r}]$ are enhanced. The matrix $\mathfrak{M}(\gamma_5 \mathbf{r})$ does not play any significant role since its cross term with the main matrix $\mathfrak{M}(\boldsymbol{\sigma})$ has almost no energy dependence. The factors of enhancement are about 10 and 20 for $\mathfrak{M}(\boldsymbol{\sigma} r^2)$ and $\mathfrak{M}[(\boldsymbol{\sigma}\cdot\mathbf{r})\mathbf{r}]$, respectively, compared with the original estimate.[2] A possible explanation for this will be discussed.

[1] T. Mayer-Kuckuk and F. C. Michel, Phys. Rev. Letters **7**, 167 (1961).
[2] M. Morita, Phys. Rev. **113**, 1584 (1959).

K6. Steady-State Solution in Scattering Theory. FAROUK M. ODEH, *IBM Thomas J. Watson Research Center.*—The

problems of scattering of time-harmonic waves by an object or a potential are usually solved by assuming that (i) the scattered wave becomes time-harmonic with the same frequency of the incident wave as time increases indefinitely; (ii) the steady-state solution satisfies Sommerfeld's radiation condition.[1] We rigorously demonstrate the validity of such assumptions by proving that the solution to the mixed initial-boundary value problem for the inhomogeneous wave equation, with time-harmonic sources, tends, as $t \to \infty$, towards a function which satisfies the reduced wave equation, the proper boundary conditions, and the radiation condition at infinity. An analogous theorem holds for the solution of the time-dependent Schrödinger equation with a suitably restricted potential if the incident wave is time-harmonic.

[1] C. Zemach and F. Odeh, Arch. Rat. Mech. Anal. **5**, (1960).

K7. Radiation Damping of Spinning Particles. H. C. Corben, *Space Technology Laboratories, Inc.*—The disagreement in the literature on the classical equations of a spinning particle is summarized and the relations between the various theories are outlined. The basic confusion lies in the translational equation but this has led to different interpretations of the g factor in the rotational equation. The theory of a charged particle with spin is developed for the case in which radiation damping is included and the particle may possess a moment of inertia about an axis orthogonal to the spin. Precession of the angular velocity vector about the spin vector contributes an extra mass even to a particle at rest. For the case of a particle with no anomalous magnetic moment, the spin may be redefined so that the classical equations describing the translational and rotational motion and including radiation damping can be put into the form that they would have assumed if radiative effects had been neglected. The supplementary condition is no longer satisfied by the redefined spin.

K8. Statistical Independence of Probability Density Functions in the Quantum Theory of Electromagnetic Radiation. James W. Deer, *Iron Fireman.*—Apparent quantum structure of the electromagnetic field is regarded as a result of the quantum mechanical nature of our probe, the charged particle. Photoelectric effect can be dealt with without the supposition of electromagnetic quanta, by regarding the transition dipole moment as a virtual oscillator having zero logarithmic decrement except for downward transitions in which it emits radiation in the classical sense. Electromagnetic probability density functions must thus be regarded as independent rather than dependent. Coincidence counting of photoelectrons induced by a light beam split by a semitransparent mirror is capable of distinguishing statistical independence from dependence. Coincidence component due to stimulated emission can be varied by a factor of 2 by using two light sources. Experiment requires high over-all quantum efficiency. Coincidence count would be increased above random expectation by a factor of $1+(Z/2NT)$, where Z is over-all quantum efficiency, T is resolving time of counter, and N is photoelectron counting rate.

K9. Influence of the Rotational Levels on the Scattering of Slow Neutrons by Gaseous Methane.* G. W. Griffing, *Phillips Petroleum Company.*—The partial differential cross section for the scattering of slow neutrons by gaseous methane has been computed for scattering angles of 16.3° and 26.0° at incident neutron energies of 0.015 and 0.0252 ev. In these computations the quantum nature of the rotational levels was taken into account explicitly. It was found that the rotational levels have a marked effect on the scattering. Comparison of the theoretical and experimental results demonstrates that such an effect has also been observed in the experiments. This is the first time that the influence of the discrete nature of the rotational levels has been noted in the scattering of slow neutrons by a gas.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

K10. Neutron Transport with Anisotropic Scattering.* Janusz R. Mika, *University of Michigan*† (introduced by Kenneth M. Case).—It is assumed that the scattering of neutrons can be represented by the scattering function consisting of the finite sum of Legendre polynomials. The general procedure of solving the resulting one-velocity Boltzmann equation in the case of plane geometry is presented. The complete set of orthogonal eigenfunctions consisting of discrete and continuous spectrum is found. The proof of completeness has a constructive character. By way of illustration, solutions of basic problems of neutron diffusion in plane geometry are given. These include: infinite half-space, two adjacent infinite half-spaces, Green's function for infinite and semi-infinite medium and Green's function for two adjacent half-spaces. The method presented can be extended for more complicated plane systems.

* Supported in part by the Office of Naval Research, U. S. Navy.
† Permanent address: Institute of Nuclear Research, Warsaw, Poland.

Thursday Afternoon at 2:00

Chemistry 2250

(R. Finkelstein presiding)

Theoretical Physics

Invited Papers

L1. Quantization of Magnetic Flux in Superconductors. N. Byers, *University of California, Los Angeles.* (30 min.)

L2. Broken Symmetries and Hidden Symmetries. Y. Nambu, *University of Chicago.* (30 min.)

L3. Title to be announced. M. Gell-Mann, *California Institute of Technology.* (30 min.)

THURSDAY AFTERNOON AT 2:00

Chemistry 2224

(H. M. MCCONNELL presiding)

Division of Chemical Physics Symposium on Magnetic Resonance

M1. Theory of Zero-Field Splittings in the Phosphorescent Triplet States of Aromatic Molecules. M. GOUTERMAN, *Harvard University.* (40 min.)

M2. ESR Investigations in Biochemistry and Biology. J. TOWNSEND, *Washington University.* (40 min.)

M3. Linear Effects of an Electric Field on the Nuclear Magnetic Resonance in MnF_2. P. S. PERSHAN, *Harvard University.* (40 min.)

THURSDAY AFTERNOON AT 1:30

Chemistry 2276

(G. L. WEISSLER presiding)

Cosmic-Ray, Electron, and Plasma Physics

N1. Electron-Photon Energies in Extensive Air Showers in the Cosmic Radiation.* JOHN R. GREEN, *University of New Mexico.*—Average electron and photon energies are found at various distances from the cores of extensive air showers by comparing the multiplicities produced under different thicknesses of lead and of water absorbers as measured through the use of two large scintillators. For distances from 2.3×10^{-2} to 1.4×10^{-1} shower units from the cores of showers of 10^5 to 10^7 particles the total energy carried by electrons and photons per electron is found to be $.36(r/r_2)^{-0.74}$ Mev per electron. The ratio of the average photon energy to the average electron energy is found to vary from 1.5 to 3.3 at different distances. Transition curves obtained with different thicknesses of water as absorber are used to show that for showers of 4.6×10^4 particles a total of 1.5×10^{12} ev is expended in the production of pions per nuclear interaction to give an inelasticity of 0.33.

* Supported by the U. S. Air Force Office of Scientific Research and the U. S. National Science Foundation.

N2. Low-Energy Gamma Rays Produced in Air and in Lead by Cosmic Rays. JAMES I. VETTE, *Convair Scientific Research Laboratory.*—Measurements have been made at 40.5°N geomagnetic latitude of gamma rays produced in lead and in air within the energy range 25–1060 kev up to altitudes of 5.4 g/cm² by means of balloon-borne scintillation counters. The gamma rays of atmospheric origin exhibit a transition curve which peaks at 70 g/cm² and is similar to transition curves for the nucleonic component but quite different from that associated with the soft electron-photon component. The measurements give a flux of 17.3 photons/cm²/sec at the peak of the transition curve; extrapolation to the top of the atmosphere gives an albedo of 5.7 photons/cm²/sec. The spectra of the photons produced in lead and in air is very similar and the production per gram of lead is found to be about 2.7 times that per gram of air. The power contained in gamma rays up to 1 Mev is estimated to be 3% of the incoming power from primary cosmic rays. The origin of these photons will be discussed.

N3. Measurements of Cosmic Ray Produced γ Rays to 3 Mev at Balloon Altitudes.* LAURENCE E. PETERSON, *University of Minnesota.*—The spectrum of γ rays produced by interaction of galactic cosmic rays in the atmosphere was measured with a balloon-borne phoswich scintillation spectrometer. The flight occurred on May 2, 1961, and reached an atmospheric depth of 7 g/cm². The phoswich consists of a 2×2.25-in. NaI (Tl) crystal enclosed in a ¼-in. plastic phosphor. The data was telemetered from a 16-channel differential pulse spectrum analyzer which covered the energy ranges from 37–675 kev and 0.180–3.4 Mev. The outstanding feature at 7 g/cm² is the prominent annihilation line at 0.5 Mev. This is superimposed on a continuous spectrum believed to be largely due to photons originating in the electronic cosmic-ray component and which are below cascade energy. The differential spectrum decreases a factor of about 300 between 37 kev and 3.4 Mev. All components of the spectrum, including 0.5 Mev, show a similar atmospheric transition effect with a maximum at about 100 g/cm². The flux at 0.5 Mev is 0.3±0.06 photons/cm²·sec at 7 g/cm². The flux extrapolated to zero depth is 0.2±0.05 photon/cm²·sec. Typical values for the ratio of counting rate to the isotropic geometry factor, 33 cm², are: 37–75 kev, 2.9 counts/cm²·sec; 210–415 kev, 0.76; 630–1.0 Mev, 0.18; 1.0–1.85 Mev, 0.13; 1.85–3.4 Mev, 0.065.

* Supported by the National Aeronautics and Space Administration.

N4. Proposed Method of Accelerating Space Vehicles to Relativistic Velocities. ALFRED A. KRAUS, JR., *New Mexico Highlands University.*—It is clear that in order to accelerate space vehicles to velocities near the speed of light, one cannot load them initially with enough energy or mass. However, the vehicle could be designed to collect photons and protons along its route. The photons are converted to energy to provide a voltage gradient along the vehicle. Collected hydrogen is ionized and accelerated toward the rear to provide thrust. Two constraints are imposed. There must be a sufficient number of photons and protons along the path. Also, it would be advantageous to accelerate the vehicle in a short time, say one month. These can be met if the vehicle is "dropped" off of the orbit of the earth so it could intercept photons and hydrogen near the sun. If the path is too far from the sun, not enough of these will be collected; if too close, the vehicle will melt. The data for this decision would come from an appropriately designed probe dropped into the sun to measure proton density and temperature distribution. Expected limits of proton density and design details, and expected behavior, will be discussed. The long-range program is to send a vehicle to α Centauri, photograph any solar system there, and return.

N5. Magnetic Effects in a Plasma Column Irradiated with Microwaves. W. D. HERSHBERGER AND IRENE PETROFF, *University of California, Los Angeles.*—A plasma column placed in such a fashion that the electric field of an incident microwave and its direction of propagation are both perpendicular to the axis of the column displays a strong resonance as shown in reflection experiments. In the present work, the column is irradiated by two waves of the same frequency with a phase difference between them at the column of 90°, and arranged so that the directions of propagation of the two waves and the axis of the column are mutually perpendicular. The purpose is to impart a coherent circular motion to the electrons, thereby giving rise to a bulk magnetic moment directed along the column. Changes in magnetization are detected by means of a 20-turn coil placed on the column near its irradiated position. Experiments were conducted at 3000 and 9400 Mc with 10 kw pulses 2 μsec long. Radius of gyration is calculated from a knowledge of the relationship between amplitude of electronic motion and power in the associated radiation field. Induced voltage in the coil is calculated by conventional methods. In addition to a voltage at the onset and cessation of the pulse, other voltages are observed attributed to instabilities in the column.

N6. Hollow-Cathode Strontium Plasma Source.* H. F. RUGGE, G. A. PAULIKAS,† ROBERT V. PYLE, AND J. W. STEARNS, *Lawrence Radiation Laboratory, Berkeley.*—A highly ionized strontium discharge is described. Strontium vapor is fed from an oven into a tantalum tube of 0.2-cm i.d. A hollow-cathode discharge up to 50 cm in length is confined in the radial direction by a magnetic field. Typical voltages and currents are 35 v and 25 amp. Because of the rapid wall pumping of neutral Sr, the minimum neutral gas pressure in the 20-cm-diam vacuum vessel is determined by outgassing. (For experiments requiring lower Sr^+ partial densities the oven temperature is reduced and argon is fed through the hollow cathode. In this case the neutral pressure in the tank is about 1 μHg.) Langmuir-probe measurements indicate that the electron density approaches 10^{14} cm^{-3} just outside the bright central core (radius approximately 0.2 cm). Several modes of operation have been observed, as well as oscillations qualitatively attributable to large-amplitude ionic sound waves.

* Supported by the U. S. Atomic Energy Commission.
† Present address: Aerospace Corp., El Segundo, California.

N7. Vibrational and Electronic Excitation of O_2 by Electron Impact.* G. J. SCHULZ AND J. T. DOWELL,† *Westinghouse Research Laboratories.*—Low-energy inelastic collision processes in O_2 are studied using the trapped-electron method[1] with nearly monoenergetic electron beams. Peaks in trapped-electron current are observed which may be interpreted as due to vibrational excitation of the $v=1$ through $v=8$ levels of the O_2 ground state. Two of these peaks may be considered, at least in part, as possibly arising from excitation of the $^1\Delta g$ and $^1\Sigma g^+$ states. Approximate cross sections at 0.16 ev above threshold are equal or less than 3×10^{-20} and 6×10^{-21} cm^2 for the $^1\Delta g$ and $^1\Sigma g^+$ states, respectively. Most electronic levels for atoms and molecules have cross sections of the order of 10^{-18} cm^2 at 0.16 ev above threshold and the values found above are surprisingly low. Many peaks due to inelastic processes are observed in the energy range 5 to 12 ev. Interpretation here is difficult, but there is general agreement in onset energies with existing optical absorption data.

* This research was supported in part by the Advanced Research Projects Agency and the Office of Naval Research.
† Present address: Physics Department, University of California, Berkeley, California.
[1] G. J. Schulz, Phys. Rev. 116, 1141 (1959).

N8. Multiple Electron Beam Scattering in a Neutral Gas. P. PARZEN, *Republic Aviation Corporation.*—Expressions are derived for the moments of the distribution function of an electron gas created by the passage of an electron beam through a slab of neutral gas. A spherical harmonic method including the effects of energy loss is used. No special assumptions as to the angular behavior of the scattering cross sections are made except that they are independent of speed. For completeness, the case of no energy loss is also considered.

N9. Pressure Dependence of the Transfer Discharge Mechanism. ERICK LINDMAN, JR., AND K. R. MACKENZIE, *University of California, Los Angeles.*—The transfer mechanism[1] is a technique for generating an electrical discharge which does not require electron emission from surfaces. The minimum configuration consists of three electrodes of similar but arbitrary shape lined up along a magnetic field. The center electrode provides a controlled dc potential barrier between two potential wells adjacent to the outer electrodes, or anodes, which are held at a positive dc level. Rf is added between the anodes and causes the electrons to alternately spill across the barrier. This action uses every newly formed electron to help sustain the discharge and results in voltage initiation levels which approach the ionization potential of the gas. With the geometries and magnetic fields used so far the threshold is roughly constant from 10 to 0.1 μ and rises outside these limits. The current dependence with pressure is approximately the same as in the Penning discharge and suggests that this device could be the basis for a vacuum gauge with long useful life since no filament is required and sputtering effects at the low voltages employed are negligible. Some data on a prototype gauge will be presented.

[1] L. K. Hansen and K. R. MacKenzie, Bull. Am. Phys. Soc. 6, 357 (1961)

N10. Resonance Effects in the Transfer Discharge Device. THOMAS W. KARRAS AND ROBERT P. JAMES, *University of California, Los Angeles.*—Continuing studies of the transfer discharge have uncovered the existence of two additional exciting mechanisms that are characterized by breakdown at rf voltages well below the ionization potential of the gas. The electrons are excited up to ionizing energies by interacton with the oscillating potential inside the wells in which they are trapped. These interactions are described mathematically by equations which differ from the Mathieu equation only in their nonlinearity. Electrode configurations have been constructed that simultaneously excite these mechanisms as well as the transfer discharge. At frequencies above 10 Mc the rf voltage required for breakdown is well below the ionization potential of the gas over a wide range of the other parameters affecting the discharge. Experimental details and a general theory will be discussed.

N11. Chemionization in Recombination Reactions. C. R. GATZ, F. T. SMITH, AND H. WISE, *Stanford Research Institute.*—The chemical energy of a gaseous system can be directly converted to ionization if the exothermicity of the chemical reaction exceeds the ionization potential of a reaction product or another gas constituent. A tabulation of ionization potentials and heats of reaction indicates that in general recombination reactions are required in order for chemionization to occur. General mechanistic aspects of such reactions are discussed. A review is given of experimental investigations of of ionization of various species in active nitrogen. An apparent rate constant for the reaction $N+N+NO+ \rightarrow N_2+NO^++e$ has been obtained from saturation current measurements.

N12. Mutual Dependencies of the Nitrogen 1st Positive, 1st Negative, and 2nd Positive Bands in the Pink Afterglow. ROBERT A. YOUNG AND ROBERT A. SHARPLESS, *Stanford Research Institute.*—Using filtered photomultipliers the relative variation of the 1st positive and 2nd positive bands of N_2 and the 1st negative bands of N_2^+ occurring in the pink nitrogen[1] afterglow has been measured over a large pressure range. The

dependence of the 2537 Hg I line excited in this glow upon the nitrogen band systems have also been obtained. These emissions are affected (quenched) by a 60 kc electric field and the fractional quenching of each has been measured as a function of pressure and their original intensity. A discussion of the excitation mechanisms of the pink glow will be attempted using these new measurements.

[1] G. Beale, Jr., and H. P. Broida, J. Chem. Phys. 31, 1030 (1959).

THURSDAY EVENING AT 7:30

(Cocktails from 6:30)

Miramar Hotel

(F. SEITZ presiding)

Banquet of the American Physical Society

After-dinner speaker: LELAND J. HAWORTH, *U. S. Atomic Energy Commission.*

FRIDAY MORNING AT 10:00

Franz 104

(RONALD GEBALLE presiding)

Symposium of the Division of Electron Physics

O1. Charge Changing Collisions of Protons and Hydrogen Atoms. THOMAS M. DONAHUE, *University of Pittsburgh.* (30 min.)

O2. Excitation in Ion-Atom and Atom-Atom Collisions. NATHANIEL P. CARLETON, *Harvard University.* (30 min.)

O3. Theory of Heavy Particle Collisions. BERNARD A. LIPPMAN, *Lawrence Radiation Laboratory, Livermore.* (30 min.)

FRIDAY MORNING AT 9:30

Chemistry 2250

(H. K. TICHO presiding)

Experimental High-Energy Physics

P1. Recent Spark Chamber Experiments at LRL. W. A. WENZEL, *Lawrence Radiation Laboratory, Berkeley.* (30 min.)

P2. Pion-Pion Interaction. W. D. WALKER, *University of Wisconsin.* (30 min.)

P3. "Elementary" Particles and Resonances. A. H. ROSENFELD, *University of California and Lawrence Radiation Laboratory, Berkeley.* (30 min.)

P4. Recent High-Energy Experiments at Brookhaven. R. L. COOL, *Brookhaven National Laboratory.* (30 min.)

P5. Experimental Evidence on the Structure of the Muon Capture Interaction. V. A. TELEGDI, *EFINS, University of Chicago.* (30 min.)

FRIDAY MORNING AT 10:00

Chemistry 2224

(K. R. MACKENZIE presiding)

Low-Energy Nuclear Physics

Q1. Nuclear Fission Induced by Radiationless Transitions in the Mu-Mesonic Atoms Th^{232}, U^{235}, and U^{238}.* JUSTO A. DIAZ, SELIG N. KAPLAN, AND ROBERT V. PYLE, *Lawrence Radiation Laboratory, Berkeley.*—The time distribution of fissions in Th^{232}, U^{235}, and U^{238} induced by μ^- mesons was measured with a multiplate, gas-scintillation, fission chamber.

A small but statistically significant excess of prompt fissions was observed. The preliminary results are

Nucleus	Ratio of excess prompt fissions to fissions from nuclear capture
Th^{232}	0.063 ± 0.020
U^{235}	0.117 ± 0.017
U^{238}	0.072 ± 0.013

The work of Mukhin *et al.* shows that the relative intensities of μ-mesonic K x-rays for these elements relative to Pb are 0.85 ± 0.0? (Th), 0.71 ± 0.05 (U^{235}), and 0.77 ± 0.04 (U^{238}).[1] This intensity reduction is qualitatively consistent with earlier predictions that, for these elements, a direct excitation of the nucleus competes with electromagnetic radiation in the transition to ground state of the mesonic atom. Our results indicate such direct nuclear excitation.

* Work sponsored by U. S. Atomic Energy Commission.
[1] A. I. Mukhin, M. J. Balatz, L. N. Kondratiev, L. G. Landsberg, P. I. Lebedev, Yu. V. Obukliov, and B. Pontecorvo, in *Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester* (Interscience Publishers, Inc., New York, 1960), p. 550.

Q2. Muon Catalysis of Fusion $p+d \rightarrow He^3+\gamma$.* J. Rosen, E. Bleser, L. Lederman, J. Rothberg, and E. Zavattini,† *Columbia University.*—Mu catalysis of the fusion reaction $p+d \rightarrow He^3+\gamma$ (5.4 Mev) has several aspects of interest. It serves as a tractable method of observing the fusion process initiated in an s wave state, affords an opportunity to study the molecular three-body systems $p\mu p$ and $p\mu d$ and perhaps most important, provides the information necessary to the unfolding of the molecular effects in the μ-capture process in liquid hydrogen. The yield of fusion γ rays from pure hydrogen as a function of time relative to the μ^- stopping and deuterium concentration has been recorded. Concentrations of 5, 110, 220, 440, 900, 8000 ppm D_2 were studied. Analysis to date yields the following: $\lambda_{\text{fusion}} = (2.9 \pm 0.3) \times 10^5 \text{sec}^{-1}$, $\lambda_{(d\mu+p \rightarrow (d\mu p)^+)} = (5.4 \pm 1) \times 10^6 \text{ sec}^{-1}$, $\lambda_{(p\mu+d \rightarrow d\mu+p)} = (1.7 \pm 0.5) \times 10^{10} \text{ sec}^{-1}$, and $\lambda_{(p\mu+p \rightarrow (p\mu p)^+)} = (1.4 \pm 0.4) \times 10^6 \text{ sec}^{-1}$. Further analysis of the data at hand will yield smaller limits. Future experiments which might yield information concerning the hyperfine dependence of λ_{fusion} will be discussed.

* This work is supported in part by the Office of Naval Research.
† Present address: CERN, Geneva, Switzerland.

Q3. Muon Capture in Liquid Hydrogen $\mu^-+p \rightarrow n+\nu$.* E. Bleser, L. Lederman, J. Rosen, J. Rothberg, and E. Zavattini, *Columbia University.*—Several hundred events of muon capture in ultra pure deuterium free liquid hydrogen have been observed. Palladium-filtered hydrogen gas (estimated impurities $\ll 1$ part in 10^9) was introduced into a carefully outgassed chamber where it was liquified by thermal contact with ordinary liquid hydrogen. The 5.3 Mev neutron induced proton recoils constituted the events. Background was reduced to less than 10% by: (i) the use of considerable shielding; (ii) high Z target walls; (iii) μ^- time gating, anticoincidence requirements; (iv) a highly purified beam ($\ll 1\%$ pions and electrons) improved duty cycle ≈ 3; (v) n-γ pulse shape discrimination; and (vi) recoil energy discrimination. The 8.9 Mev neutron from π^- capture was separately measured as a control experiment. Data reduction and Monte Carlo calculations of efficiency in the experimental geometry finally adopted are underway. Rough estimates indicate that the data is compatible with the $V-A$ form of intrinsic weak coupling as opposed to $V+A$. Time gating restricted the observed capture to that from the molecular ion $(p\mu p)^+$. The measured $(p\mu p)^+$ formation rate suggests that by reducing the number of μ^- stopping in the target walls and/or lowering the temperature of the hydrogen, it should be possible to observe the prompt pure singlet atomic capture as well.

* This work is supported in part by the Office of Naval Research.

Q4. $\mu^-+C^{12} \rightarrow B^{12*}+\nu$.† R. M. Edelstein, E. J. Maier, and R. T. Siegel, *Carnegie Institute of Technology.*—Observation has been made of de-excitation γ rays from the bound excited states of B^{12} in the reaction $\mu^-+C^{12} \rightarrow B^{12*}+\nu$. The B^{12*} nucleus, recoiling from the muon capture, was detected (using a liquid scintillant target) in coincidence with its nuclear γ ray (observed in NaI). In addition a delayed coincidence was made with the β ray from B^{12} decay. The γ-ray energy spectrum showed a peak which is attributed to the 0.95 Mev level of B^{12}. The present experiment yields a correction to an earlier result[1] for μ^--carbon capture to all bound states of B^{12}, thus enabling us to obtain the rate for capture to the B^{12} ground state. This number will be presented. It is suggested that the observation of the nuclear recoil offers the possibility of simplifying certain other μ capture experiments.

† Research supported by the U. S. Atomic Energy Commission.
[1] E. J. Maier, B. L. Bloch, R. M. Edelstein, and R. T. Siegel, Phys. Rev. Letters 6, 417 (1961).

Q5. An Experimental Test of the Law of Conservation of Nucleons.* C. C. Giamati† and F. Reines, *Case Institute of Technology.*—An improved measurement has been made of the lower limits of the lifetime of nucleons against spontaneous decay by processes which do not conserve the number of nucleons. A detector containing 198 liters of liquid scintillator was constructed to detect possible decay events. A Čerenkov counter anti-coincidence shield consisting of a water tank 2.7 m in diameter and 2.2 m high viewed by 52 DuMont type 6364 photomultiplier tubes surrounded the detector and the experiment was carried out in a salt mine 585-m underground to reduce cosmic-ray background. The system was set to detect pulses as low in energy as 8 Mev and hence was sensitive to a wider variety of decay events than previous experiments. The lifetime limits obtained for various decay modes varied from 1.3×10^{26} years for free protons to 7×10^{27} years for bound nucleons.

* Work supported by U. S. Atomic Energy Commission.
† Work performed while on leave from N. A. S. A., Lewis Research Center.

Q6. Range of Heavy Ions in Solids.* R. D. Powers and W. Whaling, *California Institute of Technology.*—The ranges of N, Ne, A, Kr, and Xe ions in Be, B, C, and Al have been measured to $\pm 10\%$ for incident ions energy 50–500 kev. A monoenergetic ion beam from an electrostatic accelerator strikes a thick target of the absorber, and the penetration depth is determined by a momentum analysis of monoenergetic protons elastically scattered from the target and the embedded atoms. An expression relating the penetration depth to the actual path length is derived. A linear range-energy behavior is found for A, Kr, and Xe ions; for N and Ne ions dE/dX increases with ion energy. The experimental ranges are 20% shorter than theoretical values based on energy loss by elastic nuclear collisions. By including electronic contributions to the stopping process, good agreement with experiment is achieved.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

Q7. Measurement of the Range Energy Relation for Alpha Particles in Air. Hans Bichsel, *University of Southern California.*—Alpha particles from Bi^{212} (6.05 Mev) and Po^{212} (8.78 Mev) in a thin source, travel through a layer of air of measured thickness t and impinge on a silicon solid state detector, where their residual energy E_2 is measured with an accuracy of better than 1%. As the source is moved away from the detector E_2 decreases and the range energy curve can be constructed from a graph of t vs E_2. This method is similar to the measurements in which ionization chambers are used,[1] but is more reliable because the energy w for the formation of an electron-hole pair is smaller and less energy dependent for solid-state detectors than for gases. A correction for the in-

sensitive surface layer of the detector has to be applied but is less than 20 kev. The over-all accuracy of the experiment is about 1% and will be improved. The agreement with the previously known data[1] is within this accuracy. Some theoretical calculations done in conjunction with the experiment indicate that the I value for air should be chosen to be about 85 ev.

[1] W. P. Jesse and J. Sadauskis, Phys. Rev. **78**, 1 (1950).

Q8. Experimental Study of Reactor Induced Radiation Heating in Materials.* O. H. Hill and E. E. Kerlin, *General Dynamics, Fort Worth.*—An experimental study has been performed to measure the nuclear reactor induced radiation heating rate in lead, 1018 steel, Marlex type 2 polyethylene, and an 80% LiH-20% polyethylene matrix material in order to provide data for comparison with predictive methods employing computer techniques. Thermal transducers of these material types were fabricated to provide for measurement of rates of temperature rise at some 9 to 12 isolated planes in the material. The transducers were embedded in slabs of material which approximated an infinite half-plane configuration exposed to the reactor. Data will be presented for heating rates observed on the reactor centerline and various off-center positions.

* Work performed under U. S. Air Force contract.

Q9. Energy-Loss Distributions for 624-Kev Electrons in Beryllium. Felix Schweizer* and W. A. McKinley, *Rensselaer Polytechnic Institute.*—Energy-loss distributions for 624-kev electrons passing through beryllium were measured with a double-focusing beta-ray spectrometer. The source was a line of Cs^{137} on a 40 $\mu g/cm^2$ aluminized Formvar backing. The overall resolution was 0.25%. Experimental distributions for Be foils of 6.6, 10.4, 20.0, and 49.4 mg/cm^2 thickness were compared against Landau distributions[1] corrected for resolution by folding with the observed K line of Cs^{137}. When the thicknesses of the foils were corrected for increase in path length due to multiple scattering,[2] the most probable energy losses agreed with the theory. The distributions were wider than the Landau curves by a factor that increased with foil thickness. For the two thinnest foils, the high energy-loss tail agreed with the theory, but for the thicker foils, the observed number of electrons in this tail increasingly exceeded the predictions. The low energy-loss edge was more gradual than predicted.

* Present address: Space Technology Laboratories, Inc.
[1] L. Landau, J. Phys. U. S. S. R. **8**, 201 (1944).
[2] C. N. Yang, Phys. Rev. **84**, 599 (1951).

Q10. Measurement of Betatron Oscillation Frequencies on the UCLA 50-Mev Cyclotron.* David J. Clark and J. Reginald Richardson, *University of California, Los Angeles.*—The rf knockout technique[1] was used to measure the vertical and radial betatron frequencies, ν_z and ν_r. The circulating beam passed through the electric field between a pair of exciter plates. The extent of the plates was 1 in. radially by 8 in. azimuthally. The separation was $\frac{3}{8}$ in. An oscillator supplied the plates with voltages up to 3 kv at frequencies of 1.5–15 Mc. An electrode collected the beam after it made 10–50 rev through the plates. Curves will be shown of beam current collected as a function of exciter frequency at a number of radii. Superimposed on the main dip of the ν_z resonance are several minima with spacing $(\nu_r - 1)$ times the revolution frequency. Thus this technique gives a measurement of both ν_z and ν_r. Comparisons will be given of the measured values of ν_z and ν_r with the values calculated from magnetic field measurements.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] C. L. Hammer, R. W. Pidd, and K. M. Terwilliger, Rev. Sci. Instr. **26**, 555 (1955).

Q11. The rf System of the UCLA 50-Mev Cyclotron.* S. H. Plunket, E. Petersen, and K. R. MacKenzie, *University of California, Los Angeles.*—The accelerating system consists of biased 45° spiral dees located in the valleys at opposite ends of a line whose impedance is changed by varying the cross section of the inner conductor. The range is 25 to 30 Mc. Inductive coupling is used with a conventional grounded grid oscillator. The dees are cut from $\frac{1}{4}$-in. copper plate and cooled only at the outer radius. The dees and supporting half wave line are installed by raising the upper pole and yoke which flexes the vacuum tank. Fifty- to 60-kv dee to ground is obtained before sparking occurs in the source region.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

Friday Morning at 9:30

Chemistry 2276

(K. Dransfeld presiding)

Solid State III

R1. Renormalization of Many-Fermion Momentum-Space Distributions in Higher Random Phase Approximations.* N. R. Werthamer and H. Suhl, *University of California, San Diego.*—The approach to the many-fermion problem known as the method of higher random phase approximations (RPA) is given a more rigorous formulation. It is shown that the previous heuristic procedures for evaluation of the second RPA are justified, in that expectation values of plane wave operators with respect to the true ground state may validly be replaced by their values in the unperturbed Fermi state. This property of momentum space occupation renormalization is conjectured to hold also to higher orders of RPA than the second.

* Supported in part by the U. S. Air Force Office of Scientific Research.

R2. Influence of the Lattice Internal Energy on the Thermal Red Shift of Recoilless γ Emission. Roger E. De Wames, *Atomics International* (introduced by Guy W. Lehman).—When a nucleus emits a γ ray its mass decreases by an amount $\delta m = E_\gamma/c^2$. According to Rayleigh's theorem this causes a small rise in all the lattice vibration frequencies. This extra lattice energy is provided by the nuclear transition, so that the energy of the emitted γ ray is reduced. The existence of this effect was predicted by Josephson[1] and an expression for the change in the energy of the γ ray was derived by assuming equipartition of energy in the sense that the energy of the whole crystal is distributed equally among all atoms. The purpose of this paper is to derive a more general expression for the change in the energy of the γ ray through a more

careful consideration of the lattice dynamics. The possibilities of the Mössbauer effect to give information, through the internal energy shift, on the crystal properties are discussed.

[1] B. D. Josephson, Phys. Rev. Letters 4, 341 (1960).

R3. Axially Symmetric Model for Lattice Vibrations in Aluminum and Zirconium Hydride. THOMAS WOLFRAM AND GUY W. LEHMAN, *Atomics International*.—A lattice dynamics model is presented in which the atoms of a crystal interact with axially symmetric forces. A general expression for the interaction matrix elements arising from a shell of neighboring atoms at an arbitrary distance is given in terms of a generating function. The model is found to be applicable to aluminum yielding results comparable to those obtained by Walker, yet employing fewer atomic force constants. Application is also made to ZrH_2, which has a tetragonally deformed fluorite structure and the resulting dispersion curves for the six optical and three acoustical branches are calculated along the three principal symmetry axes. The hydrogen-hydrogen interaction is shown to be less than 4% of the zirconium-hydrogen interaction on the basis of the observed optical bandwidth so that the hydrogens closely approximate Einstein oscillators. Approximate elastic constants for ZrH_2, consistent with our model, have also been determined using the measured bulk modulus and Blackman's formula for the Debye temperature.

R4. Ground-State Energy of Bound Polarons. P. M. PLATZMAN, *Bell Telephone Laboratories, Inc.*—A variational expression for the binding energy of a single electron coupled simultaneously to a Coulomb potential and to a longitudinal optical mode phonon field, is obtained using the Feynman path integral technique. No assumption is made about the strength of the couplings. The binding is explicitly evaluated by numerically minimizing the variational expression for a set of physical parameters which correspond to cadmium sulfide. The effective mass of the electron in the periodic potential is retained as a parameter and is determined by matching the observed binding to the variational result. An effective mass of $0.2m_e$ is found to give good agreement. The results of the variational calculation are found to be consistent with a perturbation treatment of the phonon interaction.

R5. Improved Equation for Use in Theoretical Calculations of Radiation Damage.* JOHN A. BRINKMAN AND GUY W. LEHMAN, *Atomics International*.—In order to solve the integral equation of Snyder-Neufeld[1] for $g(x)$, the average total number of displaced atoms produced by a primary knock-on of energy x by use of classical mechanics, one must assume an atomic interaction potential which is identically equal to zero for all internuclear separations exceeding some fixed value, in order that the total scattering cross section be finite. Calculations of $g(x)$ which have been made to date have therefore been based on the use of hard-sphere-like atomic interaction potentials. Such calculations overestimate $g(x)$. A satisfactory approximate equation defining $g(x)$ is

$$g(x)=\int_\alpha^x [g(x-y)+g(y-\alpha)]\frac{\sigma(x,y)}{\sigma_d(x)}dy-\frac{1}{N_0\sigma_d(x)}\frac{dx}{dR}\frac{dg}{dx}. \quad (1)$$

Equation (1) requires only that the cross section for displacing an atom $\sigma_d(x)$ rather than the total scattering cross section be finite, thereby allowing one to make classical calculations based on the use of more realistic atomic interaction potentials. The notation in Eq. (1) is that of Snyder and Neufeld.

* This work was supported in part by the U. S. Atomic Energy Commission.

[1] W. S. Snyder and J. Neufeld, Phys. Rev. 97, 1636 (1955).

R6. Approximate Analytic Expressions for Scattering Cross-Sections for Radiation Damage Calculations. GUY W. LEHMAN, *Atomics International*.—Húlthen's variational procedure has been employed to derive phase shifts, $\Delta_n=-\frac{1}{2}\pi s$, in the classical region corresponding to a large angular quantum number n. The result is

$$2sL-s^2=\frac{L^2}{\pi E}\int_1^\infty dx\frac{x}{(x^2-1)^{\frac{1}{2}}}V(x\lambda L), \quad (1)$$

where $L=s+n+\frac{1}{2}$, E is the energy, $V(r)$ is the potential energy of interaction between particles at a distance r, and λ is the de Broglie wavelength divided by 2π. The method of stationary phase gives $2(d\Delta_n/dn)=\theta$, the scattering angle. For a screened Coulomb potential, one can solve Eq. (1) explicitly and obtain scattering cross sections in essentially closed form which differ by less than 1% from the classically determined numerical results. A classical variational treatment has also been discovered which leads to results identical with the above. The calculation of total scattering cross sections based on this formulation and needed in a realistic treatment of radiation damage will also be discussed.

R7. Analogy between Maxwell's Equations and a New Theory of Continuous Dislocation Density. TOSHIO MURA, *Northwestern University* (introduced by J. Weertman).—The potential energy and the kinetic energy of moving dislocations which are distributed through a material are expressed by deformation tensors and their time derivatives as a natural extension of concepts in the usual theory of dislocations. The proposed theory is found to have a number of correspondences with the electromagnetic theory, in a different way, however, from that suggested by Kroner. These correspondences are in the strength of the magnetic field and the strength of the dislocation density, the strength of the electric field and the deformation rate, the electric current and the stress, and the velocity of light and the velocity of sound. Thus, the fundamental equations for the dislocation density have the same form as Maxwell's equations of the electromagnetic field.

* This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.

R8. Dislocation Loop Length Changes Associated With the Deformation Peaks in bcc Metals.* R. H. CHAMBERS, *General Dynamics/General Atomic*.—The relaxation strengths of the pair of internal-friction peaks recently observed[1] in plastically deformed refractory bcc metals increase as the total concentration of impurities in solution decreases. It is concluded from this evidence that the peaks result from an intrinsic interaction of dislocations with the lattice. Impurities act to suppress this intrinsic interaction. It is also shown that the modulus defect measured at 4.2°K in deformed Mo is less than 2% of the modulus defect as measured above the high-temperature peak. This loop length increases with increasing temperature in two major steps corresponding to the temperatures of the internal friction peaks. The mechanism of the loop length changes is discussed in terms of thermally activated motion of certain portions of the total dislocation length.

* Supported by the U. S. Atomic Energy Commission.

[1] R. H. Chambers and J. Schultz, Phys. Rev. Letters 6, 273 (1961); Acta Met. (to be published).

R9. An Application of Nonlinear Elasticity and a Flow Law of Plasticity to Plane-Wave Propagation in Metals. MARVIN E. BACKMAN, *NOTS*.—A nonlinear elastic description of isotropic material behavior is combined with a flow law of plasticity by simple principles of irreversible processes. General expressions are obtained which relate stress to elastic strain and plastic strain rate to functions of the invariants of stress. For the strain conditions of plane waves in an extended medium, an equation is obtained which relates the rate of change of stress, to the rate of change of total strain, and functions of the invariants of stress, the total strain and the plastic strain. This equation is used as the equation of material

behavior in an analysis which uses the general procedures of the Malvern analysis of stress propagation in a strain-rate dependent material. Data on the behavior of aluminum are based on experimental studies by Hauser, Simmons, and Dorn. The available experimental data and the computational procedures limit the solutions to stress of the order of 5 kbar. These solutions have certain general features in common with measurements made at higher stresses in explosive and impact tests.

R10. Grain Boundary Relaxation in Polycrystalline Solids.* L. J. GRAHAM AND R. CHANG, *Atomics International.*—The importance of grain boundaries to sintering and high-temperature creep of polycrystalline solids, especially the refractory oxides, has been receiving renewed attention recently. The possible roles played by grain-boundary motion in sintering have been discussed by a number of workers.[1] Experimental evidence of grain-boundary motion in the densification of refractory bodies has been found in our laboratory. In high-temperature creep, the more recent work by Beauchamp, Baker and Gibbs[2] on Al_2O_3 and our work on BeO suggest strongly that creep deformation, especially the transient part, is controlled by certain diffusion-dependent processes taking place near the grain boundaries. One of the powerful methods of studying grain-boundary phenomena is by means of internal-friction measurements. Our more recent work in this regard aimed at understanding the fundamental behavior of grain boundaries will be discussed.

* Work supported by the U. S. Atomic Energy Commission.
[1] See, for example, paper by J. Hornstra, Physica **27**, 342 (1961).
[2] E. K. Beauchamp, G. S. Baber, and P. Gibbs, Physics Dept., University of Utah, Scientific Rept. to Wright Air Development Division (September, 1961).

R11. Activation Energies for the Motion of Dislocations in MgO and NaCl Crystals from Stress Relaxation Studies.* G. G. BENTLE AND R. CHANG, *Atomics International.*—The kinetics of stress relaxation at constant strain of MgO and NaCl crystals after slight straining by compression to initiate yielding was measured over wide temperature ranges. The stress relaxation data yield the following activation energies: 1.1–1.2 ev for MgO (700–1500°C) and 0.8–0.9 ev for NaCl (300–550°C) independent of the temperature of measurement. Possible interpretation of the results in terms of thermally activated motion of jogged dislocations under diminishing stress will be presented.

* This work supported by the U. S. Atomic Energy Commission.

R12. Some Elastic Properties of an Edge Dislocation Wall.* R. CHANG, *Atomics International.*—Analytical solutions of the dilational strain field of a finite-edge dislocation wall for certain configurations of the dislocation axes will be presented. (1) At comparatively large distances from the wall, the contours of equivalue dilation are approximately cylinders of circular cross section for the isotropic case and of elliptical cross section for the normally anisotropic case. A special case of anisotropy, where the cross section of equivalue dilation becomes hyperbolic and the dilational strain field becomes long range, will be described. (2) At small distances from the wall, small cylindrical regions of dilational strain field of opposite sign to that of the surrounding material are present. The possible importance of such regions as embryos for diffusionless transformation will also be discussed.

* This work supported by the U. S. Atomic Energy Commission.

FRIDAY AFTERNOON AT 2:00

Chemistry 2250

(ALFREDO BAÑOS, JR., presiding)

Plasma Physics

Invited Papers

S1. Kinetic Theory of Plasmas. NORMAN ROSTOKER, *General Atomic, San Diego.* (30 min.)

S2. Production of Highly Ionized Gases in the Laboratory for Basic Plasma Research. WULF B. KUNKEL, *University of California, Lawrence Radiation Laboratory, Berkeley.* (30 min.)

S3. Production and Containment of Hot Deuterium Plasmas. F. H. COENSGEN, *Lawrence Radiation Laboratory, Livermore.* (30 min.)

S4. Containment of Positrons in an Asymmetric Mirror Geometry. WILLARD C. JORDAN, *Lawrence Radiation Laboratory, Livermore.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Franz 104

(O. PICCIONI presiding)

High-Energy Nuclear Physics II

T1. Pion-Pion Correlations in $\bar{p}$-p Annihilations at Rest.* WONYONG LEE, WILLIAM CHINOWSKY, GERSON GOLDHABER, AND SULAMITH GOLDHABER, *Lawrence Radiation Laboratory and University of California, Berkeley.*—In a study of antiproton annihilations at 1.05 Bev/c it was shown that a marked difference exists between angular correlations of like and unlike pion pairs in the $\bar{p}$-p c.m. system.[1] This effect was attributed principally to Bose statistics.[2] More recently the appearance of a forward π^- and backward π^+ charge asymmetry in $\bar{p}$-p annihilations at 1.67 Bev/c was observed,[3] which influences the pion-pion correlations and thus questions the dominance of the Bose effect. We will report on our investigation of $\bar{p}$-p

annihilations at rest where the latter effect cannot occur. We find for annihilation events into five pions, $p+p \rightarrow \pi^+ + \pi^+ + \pi^- + \pi^- + \pi^0$, the ratio γ of the number of pion pair angles greater than 90° to those less than 90° to be $\gamma_{\text{unlike}} = 2.26 \pm 0.15$ and $\gamma_{\text{like}} = 1.14 \pm 0.10$. We also find a definite difference in the distribution of the invariant mass $Q_{\pi\pi}$ of the two-pion system for like and unlike pairs. Low values of $Q_{\pi\pi}$ are enhanced for like pion pairs.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] G. Goldhaber, W. B. Fowler, S. Goldhaber, T. F. Hoang, T. E. Kalogeropoulos, and W. M. Powell, Phys. Rev. Letters **3**, 181 (1959).
[2] G. Goldhaber, S. Goldhaber, W. Lee, and A. Pais, Phys. Rev. **120**, 300 (1960).
[3] B. C. Maglić, G. R. Kalbfleisch, and M. L. Stevenson, Phys. Rev. Letters **7**, 137 (1961).

T2. Single-Pion Production in $\pi^- - p$ Collisions at 380 Mev.* B. C. BARISH, R. J. KURZ, V. PEREZ-MENDEZ, AND J. SOLOMON, *Lawrence Radiation Laboratory, Berkeley.*—The reaction $\pi^- + p \rightarrow \pi^- + \pi^0 + p$ has been studied using a beam of 380-Mev π^- mesons from the 184-in. Berkeley cyclotron. This reaction was identified by detecting the inelastic protons in a scintillation-counter telescope by a combination of dE/dx, range, and time-of-flight methods. Proton distributions in energy from 45 to 160 Mev and in angles from 10° (lab) to the kinematical limit were measured. A preliminary value for the total cross section from our measurement is 0.39 ± 0.07 mb. Goebel and Schnitzer's calculation[1] for this reaction, in which their parameters are chosen from a fit to the total cross section for $\pi^- + p \rightarrow \pi^- + \pi^+ + n$,[2] predicts a value of 0.65 mb. A detailed comparison of the measured distributions with phase-space distributions and other theoretical models will be presented.

* This work done under the auspices of the U. S. Atomic Energy Commission.
[1] C. J. Gobel and H. J. Schnitzer, Phys. Rev. **123**, 1021 (1961).
[2] B. C. Barish, R. J. Kurz, P. McManigal, V. Perez-Mendez, and J. Solomon, Phys. Rev. Letters **6**, 297 (1961).

T3. Pion-Nucleon Interactions at 11.3 Bev.* W. B. FRETTER† AND T. F. HOANG, *Ecole Polytechnique, Paris.*—Interactions of 11.3 Bev negative pions with protons have been observed in the propane-freon bubble chamber of the Ecole Polytechnique, operated at CERN by a group under the direction of A. Lagarrigue. The chamber has dimensions 50 cm × 50 cm × 100 cm and contained 86% propane and 14% freon, which made the detection of γ rays from the decay of π^0 mesons fairly probable. In this present work, events were analyzed which appeared to be the interaction of a negative pion of the beam with a free or nearly free proton. It was possible to separate in many cases the particles originating at the pion-pion vertex from those originating from the decay of the excited nucleon, making use of the angles of emission of the particles in the c.m. system. Particular attention has been paid to events with two pions and four pions (including neutral pions) emerging from the pion-pion vertex. The incident negative pion often appears to retain its identity particularly in events with only two pions emerging from the pion-pion vertex. Dynamic quantities have been calculated for all events including 4-momentum transfer, inelasticities for the proton and the incident pion, and target masses.

* Supported in part by the Office of Naval Research.
† Fulbright Research Scholar and Guggenheim Fellow on leave from the University of California, Berkeley.

T4. Photoproduction of π^+ in Hydrogen.* DONALD MCPHERSON AND ROBERT KENNEY, *Lawrence Radiation Laboratory, Berkeley.*—The differential cross section for photoproduction of pions from protons was measured for lab photon energies of 154 to 185 Mev at 1-Mev intervals. A 4-in.-diam hydrogen bubble chamber and the Berkeley electron synchrotron were used. Of 5000 photoproductions seen, nearly 3400 were usable for calculations. The results are in good agreement with the theoretical calculations of Ball.[1] The combined measured cross sections, averaged over the c.m. angle of the pion, are: 2.71 ± 0.78, 3.48 ± 0.12, 4.62 ± 0.14, 6.07 ± 0.22, 6.47 ± 0.31, 5.74 ± 0.43, and 6.37 ± 0.71 (μb/Mev-sr), at photon energies 154, 157, 162, 167, 172, 177, and 182 Mev. The errors quoted are counting statistics only, and all data is subject to an additional correlated beam normalization error of 4.1%. The parameter A associated with the amplitude of the photopion production from pions was measured to be $(-0.397 \pm 0.552)e$, where e is the electronic charge. The error on A is entirely due to the beam normalization error.

* Supported by the U. S. Atomic Energy Commission.
[1] J. S. Ball, Phys. Rev. Letters **5**, 73 (1960).

T5. π^0 Photoproduction with Polarized Bremsstrahlung.* DARRELL DRICKEY AND ROBERT F. MOZLEY, *Stanford University.*—Measurements have been made of the asymmetry of π^0 photoproduction along and perpendicular to the electric field vector using a polarized bremsstrahlung beam. Measurements have been made at two points corresponding to the conditions 330-Mev photon energy, 90° pion c.m. angle and 235-Mev photon energy, 120° pion c.m. angle. The resonant energy point (330 Mev) can be used to determine the bremsstrahlung polarization using a purely phenomenological analysis and known photoproduction cross sections measured with unpolarized bremsstrahlung. The measurement at 235 Mev tests the need for additional terms in the dispersion theory due to the two-pion and three-pion resonances.[1]

* This work was supported by the joint program of the Office of Naval Research, the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.
[1] B. DeTollis and A. Verganelakis, Nuovo cimento (to be published).

T6. Measurement of Gamma-Ray Spectra with Good Resolution from 30 to 600 Mev.* ROBERT J. CENCE, DON L. LIND, GILBERT D. MEAD, AND BURTON J. MOYER, *Lawrence Radiation Laboratory, Berkeley.*—Two pair spectrometers were designed and built to measure gamma-ray spectra with high resolution over a wide range of energies. The first is a conventional 180° spectrometer with six scintillation counters on each side, measuring energies from 30 to 300 Mev. The second utilizes a completely new geometry, with two sets of eight counters and a converter all lying on the circumference of a circle, and measures energies to 600 Mev. An anticounter is used to eliminate events associated with bremsstrahlung in the channel. Efficiencies, including corrections for scattering loss and geometric configuration, were calculated from basic principles. Data for each of the 64 channels (in the case of the circular spectrometer) are stored in a Nuclear Data analyzer and read out on punched cards for each of 16 values of magnetic field. Spectra obtained from the two instruments compare very closely in the region where they overlap. Energy resolution of approximately 10% is obtained.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

T7. Neutral Meson Production in Proton-Proton Collisions at 735 Mev.* GILBERT D. MEAD, ROBERT J. CENCE, DON L. LIND, AND BURTON J. MOYER, *Lawrence Radiation Laboratory, Berkeley.*—The reaction $p+p \rightarrow p+p+\pi^0$ at 735 Mev has been studied by measuring gamma ray energy spectra from the neutral pion decay at three laboratory angles, corresponding to 11°, 55°, and 93° in the two-proton barycentric system. Measurements were made using two pair spectrometers and associated electronics described in the preceding paper. The energy and angular distribution of the neutral mesons were deduced from the gamma-ray spectra by means of a least squares analysis performed by an IBM 709 computer. The angular distribution is approximately given by $1+0.2\cos^2\theta$. The momentum distribution associated with the isotropic part is very nearly proportional to phase space, whereas the distribution associated with the $\cos^2\theta$ part is peaked at higher

energies. A more precise description of these distributions will be given.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

T8. Relativistic Rise in Bubble Density in Bubble Chambers.* T. HELLIWELL, *California Institute of Technology* (introduced by Robert F. Christy).— A semiquantitative explanation has been investigated for the observed relativistic rise in the bubble density along the path of highly energetic particles in bubble chambers. The most generally accepted theory of bubble formation identifies secondary knock-on electrons above a certain threshold energy as the initiators of bubbles. The cross section often used for production of these secondaries, which supposes the target electron to be free, varies as $1/\beta^2$. This dependence does not explain the rise for large energy. We have explored the use of the relativistic cross section for initially bound secondaries, which was originally solved by Møller and has been discussed by Bethe. A somewhat more accurate calculation of the cross section for ionization of light target atoms has been made. The results, in semiquantitative agreement with the bubble density in propane, explain why no rise has been seen in hydrogen, and predict the rise to be expected in helium. The relativistic rise in heavy-liquid chambers may be a good method to measure the energy of fast primaries, and in particular to distinguish between different kinds of particles.

* Supported in part by the Office of Naval Research and the U. S. Atomic Energy Commission.

T9. Refinements in Bubble Density Measurement.* L. J. FRETWELL,† D. G. COYNE, AND J. H. MULLINS, *California Institute of Technology.*—The value and error in the gap length distribution method of bubble density measurement are calculated for a given number of intervals so chosen as to minimize the error. The statistically more efficient mean gap length method with added information from the mean blob length is generalized to allow for gap filling between bubbles, presence of background bubbles, particle velocity change along tracks, and effects of track dip. Stable bubble chambers may be calibrated by use of this method on tracks stopping in the chamber. A preliminary device for automating the mean gap length method was built to work in conjunction with an overhead projection scanner. Light is accepted into a photomultiplier tube through a small slit motor driven and hand guided along a track. Transistorized electronics converts the resulting voltage wave form into number of gaps, total gap length, and total track length, with the gap discrimination level automatically reset for lighting variations. The instrument is tested by multiple runs with a varied parameter, giving the exponential gap length distribution, and by comparison with hand counts.

* This work is supported in part by the U. S. Atomic Energy Commission.
† National Science Foundation Predoctoral Fellowship.

T10. A Liquid Hydrogen Čerenkov Counter.* C. M. YORK,† *University of California, Los Angeles,* AND J. A. KADYK AND T. F. ZIPF, *Lawrence Radiation Laboratory, Berkeley.*—A Čerenkov counter using liquid hydrogen as a radiator has been constructed and tested at the Bevatron. A beam of positive particles containing both pions and protons with momentum of approximately 900 Mev/c was used to determine that the counter had an efficiency of 37% for detecting particles whose velocity exceeded the threshold velocity in the medium. For those particles whose velocity was less than threshold, the detection efficiency was less than 0.5%. The relatively low counting efficiency for fast particles can be understood in terms of poor light collection in the present model and is not an inherent limitation of the device.

* Supported by the U. S. Atomic Energy Commission.
† Partially supported by the National Science Foundation.

SUPPLEMENTARY PROGRAMME

SP1. Oscillator Strengths for Atoms with Two Electrons Outside Closed Shells.* T. HELLIWELL, *California Institute of Technology* (introduced by Robert F. Christy).—A new method is being investigated for calculating oscillator strengths in atoms having two electrons outside closed shells. This work was motivated by the hope of eliminating the need to solve the Hartree-Fock equations for the electrons composing the atomic core by making some use of experimental information. The method computes the valence wave functions from the Hartree-Fock equations for two particles, neglecting the influence of the core. This approximation is quite good, since the major contribution to the dipole moment integral comes from large radii outside the inner shells. The inner boundary condition on the wave functions is supplied by the knowledge of their nodes. The positions of these nodes are found by showing that they are nearly the same as the nodes for the corresponding valence function in the ionized atom. The latter then can be found by the well-known Bates-Damgaard approach, for one electron outside closed shells, using experimental term values. Preliminary results give close agreement with all of these wave functions previously calculated by the full Hartree-Fock treatment, except those which have made use of a phenomenological core polarization potential.

* To be called for at the end of Session K if the Chairman rules that time permits.

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Proceedings of the American Physical Society

MINUTES OF THE FALL MEETING OF THE NEW ENGLAND SECTION AT AMHERST COLLEGE, AMHERST, MASSACHUSETTS, ON OCTOBER 21, 1961

THE annual fall meeting of the American Physical Society-New England Section (APS-NES) was held on Saturday, October 21, at the Department of Physics Building, Amherst College. The program attracted a registration of 95 persons, not counting nonregistered students, friends, and members of families. Twelve contributed papers, divided in two concurrent sessions, made up the morning meeting. The abstracts are printed below.

After our very successful introduction of "Tutorial Sessions" at the previous APS-NES meeting, another tutorial session was arranged for this fall meeting. The topic chosen was "Physical Oceanography. An Introduction to Some Basic Problems of Large-Scale Oceanic Circulation: Observational Knowledge and Theoretical Models." An excellent over-all survey was provided by the chairman of that meeting, Professor Arnold Arons of Amherst College. The tutorial program, which he had organized for this occasion, continued with the following three papers:

Patterns of Density Structure and Water Movement in the Ocean: Definition of the Basic Problems. HENRY STOMMEL, *Harvard University.*

Large-Scale Features of Wind-Driven Oceanic Circulation. GEORGE VERONIS, *Woods Hole Oceanographic Institution.*

Thermal Circulation and the Problem of the Oceanic Thermocline. ALLAN ROBINSON, *Harvard University.*

All four participants in this tutorial program are colleagues on the research staff of the Woods Hole Oceanographic Institution.

The response to this tutorial session was again very favorable, and efforts will be made to continue this type of program at future meetings of the APS-NES.

At the business meeting, the Nominations Committee, consisting of Professor R. Kingsbury of Trinity College, Hartford, and Dr. R. W. Hickman of Harvard University, Cambridge, submitted the slate of candidates for office in 1961–62. The following were elected to serve, and have accepted:

E. P. Clancy, Mt. Holyoke College, South Hadley, Massachusetts: *Chairman.*
Gerald Holton, Harvard University, Cambridge, Massachusetts: *Vice Chairman.*
J. M. Davis, Quartermaster's Laboratory, Natick, Massachusetts: *Councilor.*
David Park Williams College, Williamstown, Massachusetts: *Councilor.*
Earle Fowler, Yale University, New Haven, Connecticut: *Secretary-Treasurer.*

The New England Section is indebted to Amherst College, and especially to Professors Arons, Soller, and Towne, for the excellent arrangements and accommodations which helped to make the meeting successful.

G. HOLTON
for P. J. BRAY, *Secretary-Treasurer*
New England Section (1960–61)

Contributed Papers

Session A

A1. Charge Analysis of Scattered Particles in Ion-Atom Collisions.* P. R. JONES AND I. S. FROST,† *University of Massachusetts.*—Newly constructed apparatus has been used in measurements of single collisions of Ne^+ and Ar^+ with an Ar target. The incident ions ranged in energy from 3 to 20 kev and were analyzed after suffering collisions which resulted in angular deflections ranging from 3° to 20°. These scattered incident particles at each angle were found in general to be neutral, singly ionized, or doubly ionized, corresponding respectively to the processes of electron capture, scattering without change of charge, or electron loss. The data, obtained at each of several incident-ion energies, show how the fractions P_0, P_1, and P_2 of the scattered particles in each charge state vary with scattering angle θ. The plots of P_θ vs θ show several local maxima and minima of the type reported by Ziemba *et al.*[1] and predicted earlier by Bates *et al.*[2] for resonance electron capture in atomic collisions. Measurements are continuing with a Ne target and results will be presented if available.

* Supported by the National Science Foundation.
† Now at Sperry Gyroscope Co., Great Neck, New York.
[1] F. P. Ziemba, G. J. Lockwood, G. H. Morgan, and E. Everhart, Phys. Rev. **118**, 1552 (1960).
[2] Bates, Massey, and Stewart, Proc. Roy. Soc. (London) **A216**, 437 (1935).

A2. Bright Field Photography in a Single Window Hydrogen Bubble Chamber.* DAVID R. FIRTH, *Harvard University.*—Bright field illumination systems for bubble chambers have usually used a very diffuse light field. Greater contrast is shown to be theoretically possible by using a field of light directed onto the camera lens. The improvement should be especially significant for bubbles in liquid hydrogen, which refract light through smaller angles than do bubbles in other liquids. If the bubble chamber is inside a magnet, it is advan-

tageous to have only one window. This complicates the optical system, for one must use a concave mirror at the back of the chamber to redirect the illumination, and one then sees the bubbles reflected in the mirror, as well as directly. A model has been built to see what contrast is actually possible and to try to find ways of eliminating the reflected images while still retaining the direct images at high contrast. Satisfactory results have been obtained using a narrow angle diffuser in front of the mirror. Various limitations of the proposed scheme also will be discussed, such as aberrations of the mirror, flares, and the effect of dirt on the camera lens.

* Supported by the U. S. Atomic Energy Commission.

A3. A Heavy Ion Detection System.* F. C. JOBES, T. L. WATTS, AND J. A. MCINTYRE, *Yale University.*—In typical heavy ion accelerator work a suitable target is bombarded by a beam of 0–10 Mev/amu heavy ions; most of the reaction products, predominantly stable nuclei but including also unstable nuclei, are scattered by the target. A system has been developed which can efficiently detect an important class of the scattered reaction products, those which are β^+ radioactive, and clearly discriminate between them and all other reaction products. The scattered products are collected by the stacked foil technique, in which the foil stacks can be arranged to show either angular distributions or ranges of the reaction products. The foils are put in a positron detection system, which consists of 12 NaI scintillation counters connected so that they can count in coincidence the annihilation radiation from 20 different foils or foil stacks. The efficiency and background of the counters can be controlled electronically. The foils, made by spraying parlodion on glass, have thicknesses ranging from 0.02 mg/cm² to 0.50 mg/cm², although a greater range is possible. The thickness variation is 5% over an 8 cm² area. The energy resolution of the range measurement, about 1 Mev, is limited by the straggling in the foil stack rather than by the thickness of individual foils.

* Supported by U. S. Atomic Energy Commission.

A4. Crystallographic Aspects of Electron Resonance Studies of Radiation-Damaged Single Crystals. ROY S. ANDERSON, *Clark University.*—Exposure of organic compounds to high-energy radiations results in the formation of radicals stably trapped in the surrounding material. Interpretation of the anisotropic behavior of the electron resonance spectra of radicals trapped in single crystals reveals the orientation of the molecules with reference to the crystallographic axes. It is also possible to determine the relative orientations of groups within the molecule. In contrast to x-ray methods the electron resonance technique reveals the orientations of certain hydrogen atoms. This method also proves useful in providing limited crystallographic information on organic compounds whose structure has not been determined. Examples will be given from the interpretations of unpublished electron resonance spectra of the biochemicals *d*,l-aspartic acid and *d*,l-isovaline.

A5. Carbon Monoxide Molecular Beam Frequency Standard. R. A. LEVY, *National Company.*—The need for increasingly precise time standards requires development of devices operating at higher frequencies with sufficiently narrow resonance lines. The $C^{12}O^{16}$ molecule, with a dipole moment of 0.1 debye, has a $J=0$ to $J=1$ rotational transition at 115 kMc, which can, for equal interaction times, result in a line Q an order higher than for cesium clocks. The deviation of frequency due to stray electric or magnetic fields is considerably below that of cesium. Design data for a frequency standard operating from a source pressure of 1 mm of CO at 77°K based on this transition show that 1° of deflection is possible. A two-wire electrostatic deflection system, which has coupling advantages over multipole geometries, is used for state selection. The design of a C field and rf interaction region necessary to accommodate the beam at millimeter wavelengths will be discussed. Experiments on electron bombardment ionization and detection indicate that methods of incorporating beam detection and mass spectrometry into a single unit can be accomplished. A phase-locked rf source produces approximately 1 μw at 115 kMc by diode harmonic generation from a K-band klystron.

A6. Portable 2-In. Freon Chamber for the Investigation of Beam Profiles. F. BULOS AND R. LANOU, *Brown University, and Brookhaven National Laboratory,* AND I. PLESS AND L. ROSENSON, *Massachusetts Institute of Technology and Brookhaven National Laboratory.*—In the Cambridge bubble chamber group experiment on pion production by pions conducted recently at Brookhaven the requirements on the shape of the beam were stringent. The central ray had to pass along the axis of a cylindrical target with the whole beam contained within a circle ½ in. in diameter at all points along the target (8 in. long). A portable 2-in. freon bubble chamber which was built and used to investigate the shape of the beam is described here. The chamber weighs 100 lb and has over-all dimensions of 18 in.×18 in.×7 in. It also has fine adjustment motion vertically and horizontally perpendicular to the beam and a coarse and fine adjustment motion along the beam. A graphic press camera with Polaroid film adapter views the chamber end on (facing the beam). A spherical correction lens insures orthogonal projection. With the help of the chamber the beam was investigated and required adjustments made in 4 hr.

Session B

B1. Coupling of Laser Rods. JOSEPH I. MASTERS, *Technical Operations, Inc.*—An optical maser oscillation is bounded primarily by the reflecting ends of its cylindrical rod enclosure, which is typically the order of 10^5 wavelengths long. In addition to an investigation of spatial coherence, etc., of the signal emerging from one end of the rod, a study of the correlation of the outputs from both ends should be valuable in understanding internal mode properties. This has special interest in the case of solid media, such as ruby, since typical rod lengths exceed the path difference ($c/\Delta\nu$) for which fringe contrast becomes arbitrarily small in an interference experiment. A configuration for investigating such correlation is the idea of optically coupling independently pumped parallel rods. If successful, laser oscillation now common to each rod may be observed from one end of the coupled system. In this regard some simple coupling experiments are described in which interference of signal light from separate rods occurs. In addition the fundamental advantages of coupled laster systems in terms of optical antenna gain and improvement of internal signal/noise are discussed.

B2. Optical Absorption of Single Crystal Hematite in the Region 3600 to 7000 A.* ROBERT C. VERNON,† *Clarkson College of Technology.*—The extinction coefficient of hematite (Fe_2O_3) was measured as a function of wavelength over the range 3600–7000 A. A graph of the data shows a peak at about 4400 A. The method of measurement consisted of reflecting polarized light from a polished and cleaned surface of a single crystal. Monochromatic light was produced by use of a diffraction grating together with a carbon arc for most of the visible wavelengths and a mercury arc for the violet and ultraviolet wavelengths. A Gaertner ellipsometer was used to produce and analyze the polarized light, while a multiplier phototube was used to detect the ultraviolet light, and visual detection was

used for the visible light. A comparison will be made with the results of other observers.

* This work was sponsored in part by the Research Corporation.
† Present address: Simmons College, Boston 15, Massachusetts.

B3. On the Interpretation of Measurements of Solar and Terrestrial Radiation Components. A. J. DRUMMOND AND J. J. ROCHE, *The Eppley Laboratory, Inc.*, AND A. R. KAROLI, *The Eppley Foundation for Research.*—In this paper the results of a series of investigations into the performance characteristics of radiant energy detectors, intended especially for use in the free atmosphere, are presented. In particular, the study was devoted to the effects of ambient temperature and pressure on the responsivity of thermopiles and to the introduction of appropriate thermistor circuitry to provide the desired degree of compensation. The response time relationships at various pressure levels have been examined; an empirical formulation for the prediction of radiometer response times at specific pressures has been derived. The study was further extended to include the problem of the use of wavelength selective detectors, calibrated outdoors and also under optical conditions distinctly different from those applicable to actual operation. The main objects of the present contribution constitute an attempt to augment existing knowledge of the measurement techniques of components of thermal radiation in the earth-atmosphere system and to facilitate interpretation of the assembled observations.

B4. The Physics of Tension. ERWIN J. SAXL, *Tensitron, Inc.*—The increasing interest in wires, cables, yarns, and other materials of high weight-to-strength ratio brings into renewed focus the importance of the basic principles that underlie the strength of materials and thus the tension that they can handle safely. Whereas the methods of stress analysis by means of wire strain gauges, polarized light, x-ray diffraction, and others are recognized for structural research in mechanical engineering, little basic work has been done from the physicist's viewpoint. A better understanding of the micro-molecular structure on levels going beyond the known concepts of the metallurgist and engineer seems needed. A discussion of some of the fundamentals of structure in semiconductor strain gauges and of the special alloys of high gage factor $\epsilon = (\Delta R/L)/(\Delta L/L)$ may be steps in the right direction. This paper discusses some steps to be taken toward the methodology of investigation limited by considerations of solid-state physics and the possibility of new material parameters singly and in combination. Some instruments will be shown that permit the establishment first and control thereafter of critical tensions under the dynamic conditions of moving wires and yarns.

B5. Tractatus Physico-Theologicus. JEROME ROTHSTEIN, *Maser Optics, Inc.*—As part of a program of formulating analogs of philosophical problems for a world of well-informed heat engines, we have considered the problem of creation of that world from an operational viewpoint appropriate to such a world. As the dynamical laws governing the behavior of a system are intrinsic to it, whereas actual preparation of a system involves extrinsic parameters, specification of a temporal origin is not possible operationally from within the system. If creation be viewed as the specification of logico-mathematical laws governing a universe (i.e., a "different" creation would involve a system nonisomorphic to it), rather than the operationally undefined one of establishing a temporal origin, and if the formal system be one in which science is possible, then that specification is necessarily unique (isomorphic systems are here identified). This follows from the group-theoretical natures of dynamical laws and physical objects (proof similar to uniqueness proofs for identities and inverses, and theorems on isomorphism and homomorphism). The discussion can be viewed as a physical interpretation of what might be meant by the "Uniformity of Nature," Spinoza's pantheism, or monotheism, in a world of well-informed heat engines.

B6. General Lorentz Transformation. V. PUNGA, *Rensselaer Polytechnic Institute.*—The special Lorentz transformation is derived under the assumption that x, y, z axes of the inertial frame S are parallel to the x', y', z' axes, respectively, of the inertial frame S' and that the relative velocity of S and S' is parallel to the x axis. Using the formalism of Cartesian tensors, the general Lorentz transformation is derived in a simple manner for the case when axes of S' are not parallel to the axes of S, and S' moves in an arbitrary direction with a uniform velocity.

Second Announcement of the 1962 Annual Meeting

The 1962 Annual Meeting of The American Physical Society will be held in New York City on Wednesday, Thursday, Friday, and Saturday, January 24, 25, 26, and 27, 1962. As usual, the American Association of Physics Teachers will hold concurrent sessions, and there will be a joint ceremonial session of the two societies, comprising the APS retiring presidential address and the AAPT Richtmeyer Lecture and Oersted Prize presentation. There also will be a business meeting of the Society. The official hotel for the meeting will be the Statler-Hilton, and most of the sessions will be held in the headquarters hotel. It is advisable to make your reservations for this meeting as early as possible. In order to facilitate making your reservations early, a hotel reservation blank has been printed on page 533 of this bulletin. You would be advised to fill this blank out and send it, as soon as possible, to: The Front Office Manager of the Statler-Hilton Hotel, 7th Avenue and 32nd and 33rd Streets, New York 1, New York.

In addition to the scientific sessions held in the Statler-Hilton Hotel, some sessions will be held in the Hotel New Yorker. Deadline day for the meeting is November 10, 1961. Abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Second Announcement of the 1962 Southwestern Meeting

The 1962 Southwestern meeting of the Society will be held at the University of Texas in Austin, Texas, on Friday and Saturday, February 23 and 24. The headquarters hotel for the Southwestern meeting will be the Driskill Hotel, 117 East 7th Street, Austin, Texas (mailing address: P.O. Box 43, Austin 1). In writing for reservations be sure to mention that you are coming to the meetings of The American Physical Society. Deadline date is Friday, December 15, and abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Preliminary Announcement of the 1962 "March" Meeting

The 1962 "March" meeting of the American Physical Society will be held in Baltimore, Maryland, on Monday through Thursday, March 26–29. The meeting will be devoted mainly to the Divisions of Chemical Physics, High-Polymer Physics, and Solid-State Physics, which will arrange special programs of contributed papers.

The headquarters hotel for the meeting will be the Lord Baltimore, Baltimore 3, Maryland. The Lord Baltimore Hotel has accepted the responsibility of housing our members, up to the moment when it is booked fully, and in other hotels in the region for those who write later. When writing for reservations to the Lord Baltimore Hotel, please be certain to state that you are attending the meeting of The American Physical Society.

Technical sessions of the meeting will be held at the Lord Baltimore Hotel, the Emerson Hotel, and at Johns Hopkins University.

Deadline date for this meeting is January 12 and abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Preliminary Announcement of the 1962 Summer Meeting in Seattle

The 1962 Summer meeting in the West will be held at the University of Washington, Seattle, on Monday, Tuesday, and Wednesday, August 27, 28, and 29, 1962. The Division of Electron Physics will hold a session of invited papers during the meeting.

Seattle, in 1962, will be the site of a World's Fair, the Century 21 Exposition. Members who are considering attendance at the meeting should realize that accommodations are being filled at a rapid rate, so they must act with reasonable promptness to assure any freedom of choice.

Rooms are available in University dormitories; you may write for reservations directly to the Office of Student Residences, University of Washington,

Seattle 5. The rate is $2.50 per person per night for a twin-bedded room; children can be accommodated if they need no special facilities. The office anticipates that some guests will wish to come early and/or stay after the meeting. No dormitory food service will be provided, but other campus dining facilities will be open and off-campus restaurants are within easy walking distance.

Those desiring other kinds of accommodations near the campus should write to the Edmond Meany Hotel, 45th and Brooklyn, Seattle 5, or to the Coach House, 4801 24th Avenue N.E., Seattle 5. The latter establishment offers motel-type arrangements with flexible possibilities for families.

If these suggestions do not work, you should write to Expo-Lodging Service, Seattle World's Fair, Seattle 9, for assistance. No matter which of these you elect, be sure to mention that you will be attending the meeting of the American Physical Society.

Questions concerning local arrangements for the meeting should be addressed to Professor Ronald Geballe or Professor Boris Jacobsohn, Department of Physics, University of Washington, Seattle, Washington.

The deadline for contributed papers will be June 22, 1962. Abstracts should be mailed to the local secretary, Dr. H. A. Shugart, Department of Physics, University of California, Berkeley 4, California.

Pertaining to The American Physical Society Prize Sponsored by Ford Motor Company

Members of The American Physical Society are invited to propose candidates for the 1962 American Physical Society sponsored by the Ford Motor Company. This they may do by sending their suggestions, with supporting statements, to Dr. Hershel Markovitz, Mellon Institute, Pittsburgh 13, Pennsylvania. The prize (given in 1962 for the first time) is awarded for "outstanding accomplishment and excellence of contributions in high-polymer physics." There are no restrictions with respect to nationality of recipient or with respect to the place where he did the work, and it is immaterial whether or not he is a member of the Society.

Hotel Information

Annual Meeting, New York, N. Y.—January 24–27, 1962

The Statler-Hilton is the headquarters hotel. Reservations should be sent directly to Mr. George Mahar, Front Office Manager of the Statler Hilton, in the manner directed below. Please tear off the attached and use as your room reservation blank. Be sure to specify the persons for whom reservations are being made. All rates quoted are for the room, and in the event of more than one person occupying the room the rate can be shared. If a third person is housed in the room, the cost of the extra "rollaway" bed will be added to the cost of the room.

If a room at the rate requested is not available, one at the nearest available rate will be reserved for you. Be sure to bring the confirmation slip with you as proof of your reservation. In fairness to others, please make a cancellation if your plans change. Unless otherwise requested, the hotel will hold reservations only to 6 p.m. of the day of your arrival. Checkout time is 3 p.m.

Hotel Rates

Hotel	Room and Bath for one per day	Double-Bed Room with Bath for two per day	Twin-Bed Room with Bath for two per day	Suites Living Room Bedroom and Bath for one or two per day
Statler Hilton 7th Avenue at 32nd Street	$8–$14.00	$11.00–$18.00	$15.00–$22.00	$36.00–$37.00

NOTE: All rates subject to New York City 5% hotel room tax.

Tear Off Tear Off

To: Front Office Manager
The Statler-Hilton
7th Avenue and 32nd Street
New York 1, New York

A. P. S.

Please enter my reservation for a $\frac{\text{single}}{\text{double}}$ bedroom at approx. $\$$..... to $\$$..... per day for the 1962 APS. $\frac{\text{twin}}{}$

Meeting. $\frac{\text{I}}{\text{We}}$ plan to arrive ..... and remain until .....

Print below persons in your party.

.....
Signature

.....
Address (Street or P.O.)

.....
Town or City and State

MEETINGS AND DEADLINES THROUGH APRIL 1962

Place	Meeting dates	Deadline date
Los Angeles*	December 27–29	Past
New York	January 24–27, 1962	Past
Austin	February 23–24	December 15
Baltimore	March 26–29	January 12
Washington	April 23–26	February 9
Evanston	June 19–21	April 13
Seattle*	August 27–31	June 22

Abstracts for the meeting marked with an asterisk are to be sent to Professor H. A. Shugart, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date. Abstracts for the other meetings listed above are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 p.m. For meetings handled at this office, *allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west.* Abstracts postmarked (at the point of dispatch) on deadline day are instantly rejected. No abstract postmarked (at the point of dispatch) on deadline day ever reaches the office on time, nor does any abstract postmarked at any point west of the Rockies on the day before deadline day. Some abstracts arrive with covering letters dated three or more days before the postmark; it may be a good idea for you to put your abstract into a United States mail box with your own hands. Finally, if time is scant, fold your abstract and mail it in an envelope of size $9\frac{1}{2}$ by $4\frac{1}{4}$ inches or thereabouts; for if you mail it in a "manila" envelope large enough to accommodate it without folding, it may very well arrive after the deadline. *The privilege of contributing papers to meetings of The American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words or to its actual length in words, whichever is the greater; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words. By-lines are not counted as part of the 200 words, and therefore addresses are condensed to the minimum in them. If you want to spend a lot of your precious 200 words in describing your exact location and the exact compartment of your organization in which you work, you have that privilege.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; *one must be an original*, the other may be an original or a carbon copy. *Carbon copies will not be accepted in lieu of originals:* they smear. *Abstracts* (including titles, by-lines, and footnotes) *must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. *Each abstract must be confined to a single page:* if it is too long for a single page it is too long to be printed. If we receive an abstract typed on two pages, we print only its first page. *Write each abstract as a single paragraph:* the suppression of paragraphs costs time and labor to the editors. *Do not use very thin paper:* a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. *Tables too broad to fit into one column of the Bulletin will be left out.* The American Institute of Physics will bless you if you type first the title of your abstract in lower-case with capitalized initials, then your name in capitals, then the name of your institution in lower-case underlined with capitalized initials. It is a pleasure to report that those who qualify for this blessing are increasing in number but are still quite a bit short of 100% of the total. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go into the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It has now become an expensive business to make any change in an abstract, even the smallest, after it has been received. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

New Instructions

(*a*) *If it is wished that two abstracts be scheduled consecutively, write on the first "To be scheduled before abstract ..... by ....." and on the second "To be scheduled after abstract ..... by ....."*

(*b*) *In general, all instructions about an abstract should be typed at the bottom of the page that has the abstract on it, never in a covering letter. Covering letters get separated from abstracts!*

(*c*) *If a member insists that his paper be scheduled for a particular day or not on a particular day, he will get his wish, but usually at the price of having his contribution included in a session to which it is irrelevant.*

The American Physical Society

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